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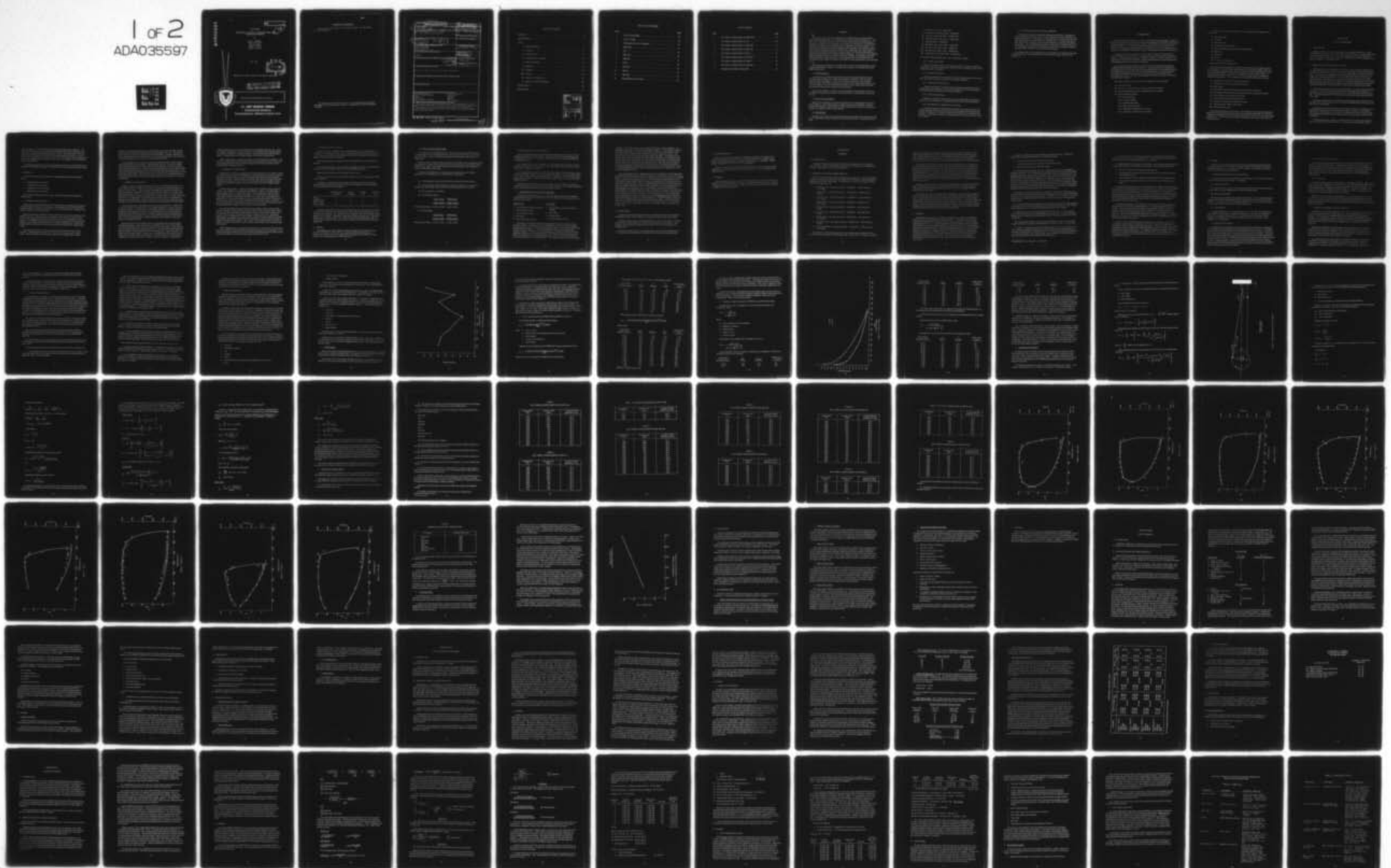

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ENGINEERING IN SUPPORT OF ARTILLERY METAL PARTS MODERNIZATION PROGRAM

by

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June 1976

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Manufacturing Technology Directorate

U.S. ARMY ARMAMENT COMMAND
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This project identified the present state of manufacturing art in projectile metal parts plants. Specific studies were undertaken to advance the observed state-of-the-art and suggested improvements were presented.

Recommendations for future manufacturing methods and technology (MM&T) programs were developed.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

ABSTRACT

This report covers the effort conducted under MM&T Project Number 5736550 titled "Engineering In Support of Artillery Metal Parts Modernization Program." This project was accomplished as part of the US Army manufacturing technology program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques, and equipment for use in production of Army material. The project had as its purpose a study to identify the present state of the manufacturing art in our existing facilities and having identified such, suggesting areas where improvements can be made either directly or, when necessary, through the implementation of Manufacturing Methods and Technology (MM&T) programs. The purpose of the suggested MM&T programs would be to resolve or alleviate particular manufacturing problems identified during the study and improve an existing operation by reducing the cost of that operation thru reduction of scrap, direct labor, energy requirements, raw materials, etc.

The following investigations were undertaken to assist in the determination of what process modifications, changes, and studies are necessary for artillery metal parts plant modernization:

(1) Literature Survey

A survey of the existing technical literature both within the Frankford Arsenal Libraries and the Industry as a whole was conducted to establish a base for future activities under this program. This survey included evaluation of recent studies conducted under other MM&T programs and prior in-house engineering activities such as warm forming. Based on the literature available, some of these prior activities such as warm forming were extended into this program.

This survey included a review of the existing methods of manufacture such as the conventional hot forge-heat treatment, hot cup-cold draw, cold extrusion, warm forming, etc.

(2) State-of-the-Art Studies

Studies were undertaken to determine the latest state of manufacturing art used in private industry, and its applicability to artillery metal parts production. This was accomplished through a contract with the Budd Company which surveyed the Automotive Industry and supplied reports of their findings.

(3) Plant Surveys

Surveys of nine metal parts manufacturing plants were undertaken to determine what areas of manufacture could be improved for plant modernization. The plants surveyed were:

I. Berwick U.S. Steel - 8 Inch M106

II. Burlington Army Ammo Plant - 81MM M374

III. Gateway Army Ammo Plant - 175MM M437

IV. Louisiana Army Ammo Plant - 155MM M107

V. National Presto - 105MM M1

VI. Riverbank Army Ammo Plant - 81MM M374

VII. St. Louis Army Ammo Plant - 105MM M1

VIII. Scranton Army Ammo Plant - 155MM M107

IX. Twin Cities Army Ammo Plant - 155MM M107

(4) Specific Additional Studies were also undertaken as follows:

(4.1) "Warm Form Study"

Based on available literature at Frankford Arsenal, a study was undertaken to determine if the spheroidizing cycle necessary for the machining of HF-1 Steel projectiles could be eliminated.

(4.2) "Ceramic Tool Study"

A Study was performed to determine if the claimed higher speeds and feeds of these tools could be used to advantage in metal parts machining.

(4.3) "Solid State Switching Study"

A study was conducted to determine what advantages and problems would be encountered by the utilization of solid state switching in lieu of the conventional mechanical relays used widely in our existing facilities.

(4.4) "Chip Transport Study"

A study was undertaken to determine if a proven and reliable chip transport system existed in industry and its applicability to projectile MPTS manufacture.

(4.5) "Development of a Math Model for Forming"

A study was conducted at Frankford Arsenal and in part under contract with Battelle Columbus Laboratories to determine if conventional forming operations involved in manufacture of artillery projectiles lend themselves to mathematical modeling. A particular operation, the draw operation, was selected as the vehicle for evaluation.

(4.6) "Feasibility of Heat Treatment by Induction"

The literature survey revealed that induction heat treatment, although now being considered in industry, had never been considered for use in artillery ammunition metal parts. Consequently, a feasibility study developed thru discussion with induction heat treatment equipment manufacturers. A contract was placed with TOCCO Corp. to provide the necessary evaluation to determine feasibility of this process. The 155MM M107 projectile was selected for evaluation because of the availability of projectiles and the large amount of data available at Frankford Arsenal on other methods of heat treating this projectile.

The findings of the above mentioned surveys and studies are contained in the body of this report under the appropriate section such as billet parting, forming, heat treating, etc.

INTRODUCTION

When Frankford Arsenal became involved in the modernization program, it appeared that many of the GOCO facilities were implementing programs without fully considering an integrated approach to modernization. Further, it was found that due to the pressure of on-going business, i.e., meeting production schedules, resources, return on investment, etc., the company operated plants could not provide the engineering know how to evaluate other production methods and develop a truly integrated modernization program.

Frankford Arsenal recommended an initial study be conducted to determine the status of the present state-of-the-art of manufacture and how it might be incorporated into our existing production facilities. Frankford Arsenal, of course, would have the advantages of visiting all the facilities involved and dedicating the required engineering talent specifically to the task under consideration.

The study prepared by Frankford Arsenal was titled "Engineering in Support of Artillery Metal Parts Modernization Program." This study had as its main purpose the identification of the present state of the manufacturing art in our existing facilities, the establishment of areas where improvement could be made to alleviate particular manufacturing problems that might exist or reduce the cost of the produced item that might exist or reduce the cost of the produced item thru some form of modernized manufacturing techniques.

The study consisted of several areas of investigation as outlined below:

(1) Literature Survey

(2) State of the Art Survey under Contract with Private Industry

(3) Ammunition Plant Surveys by Frankford Arsenal Personnel

(4) Specific Additional Studies

- (4.1) Warm Forming
- (4.2) Ceramic Tooling
- (4.3) Solid State Switching
- (4.4) Chip Transport System
- (4.5) Mathematical Modeling for Forming
- (4.6) Feasibility of Induction Heat Treating

The Body of this report is divided into several sections based on operations as listed below:

(1) Billet Separation

(2) Forming

(3) Metal Removal

(4) Heating and Heat Treatment

(5) Material Handling Including Chip Transport System

(6) Inspection

(7) Equipment

(8) Energy

(9) Summary of Conclusions

(10) Summary of Recommendations

Based on the recommendations contained in this report specific MM&T projects were prepared. It is believed that implementation of the proposed MM&T effort will lead to an integrated engineering program and provide the basic knowledge for modernized production facilities. Further, upon completion of these MM&T projects, a "Manufacturing Technical Data Package" should be available based on modernized concepts of manufacture. This technical data package would include the following:

(1) Appropriate metal parts technical data package

(2) Description of process and production method

(3) Plant Layout

(4) Description and list of manufacturing and inspection equipment.

(5) Description and drawings of material handling and chip transport system.

(6) Tool designs if not considered proprietary

(7) Layaway manual for equipment and plant

(8) Maintenance manuals and equipment drawings

(9) Energy and other utility requirements

(10) Pollutant output or load

The technical data package will serve as the foundation for all future modernization programs for each specific plant and will provide necessary information for evaluation of production capabilities under mobilization conditions or change over to produce similar artillery items. This technical data package will be under the control of the cognizant technical agency.

SECTION ONE

BILLET SEPARATION

A. INTRODUCTION

Billet separation consists of parting specific units called multiples or "mults" from billets as received from the steel mill. These billets vary in length but generally are about twenty feet long. They are usually shipped by rail but can be shipped by truck. The billets are usually stored outside and adjacent to the billet separation area where the billets are broken into mults.

B. PROJECTILE MANUFACTURING PRACTICE

Billet separation is accomplished in a variety of ways. One plant employing the hot cup-cold draw process saws round cornered square billets into thirty pound mults. The steel by nature of the process is low carbon, specifically, in this case AISI 1018 steel. The cutting is accomplished in automated Do-All continuous blade type saws. Cutting time is approximately fifty seconds for cutting thru a little over 12 square inches of metal. The cuttings are referred to as Kerf and represent lost material in this operation plus the end of the bar which is not sufficient in length for use as a mult. Cutting of lower carbon steel is generally more easily accomplished than the higher carbon steels which have a higher hardness unless given a special heat treatment.

Three plants all using the hot cup-cold draw process used cold shearing for billet separation. One of these plants manufactured the Eight Inch M106 Projectile and cold sheared seven and three-eighths inches (7 3/8 inch RCS) round cornered square bar. This plant also used flame cutting for a backup and for separating the last mult on the billet.

Two plants manufacturing the 81MM M374 projectile cold sheared AISI 1340 steel. One plant processed two and one half (2 1/2) inch round billet and the other processed three (3) inch round billets.

Four plants where the conventional hot forge heat treatment was employed accomplished billet separation by the Nick and Break method. Nicking is accomplished usually by an oxyacetylene torch. Nicking is usually done by a gang of these torches set at predetermined distances apart and the gang of torches sweep across the width of the billet.

This operation causes a change in microstructure where untempered martensite occurs immediately below the nicked area. In all cases the steel used is medium

carbon or higher. The usual carbon range being from AISI 1045 to AISI 1061. This carbon content causes a rather hard untempered martensite to occur under the nick and acts as a notch for the ensuing operation - Break. The nicked billet is fed into a press where the side of the billet opposite the nicked portion is located over a pivot point. The press applies a force to the nicked side of the billet causing a bending movement and eventually failure or fracture in this case. The multiple is then transported to the next operation.

One plant using carbon steel in the sixty (60) carbon range used flame cutting as the primary method of billet separation. This plant was not in operation during the survey.

C. CRITIQUE

Several factors must be considered in evaluating billet separation techniques, namely:

1. Weight control and variation
2. Condition of parted surface
3. Straightness of parted surface
4. Material lost due to parting.

This evaluation will consider the factors directly affecting billet separation as outlined above.

1. Weight Control and Variation

Sawing offers excellent weight control and easily meets production process requirements that might be imposed. For instance, Cold Extrusion and Hot Cup-Cold Draw normally require, or can take advantage of, close mult weight control. Sawing is used in these cases with very good success.

Cold shearing offers satisfactory weight control and it too was used for the hot cup-cold draw process. Cold shearing as employed was used only on hot cup-cold draw process where multiple weight control is not quite as severe as required for cold extrusion. It is doubtful that the cold shearing operation as employed at present could be adapted to a pure cold extrusion process but, as will be explained later, recent technology indicates cold shearing with modern equipment can bring about excellent weight control.

"Nick and Break" appears to offer the worst weight control of all the methods examined. Typical weight variation is in the order of $\pm$ 2 1/2 percent of the total weight. Many techniques have been tried to improve this condition such as closer

attention to spacing the nicking torches, nicking just one corner of the billet, nicking only the center of the flat, positive location in the breaking press, etc. All of these tend to improve or affect the operation but not significantly. It appears that the relative random location of the metallurgical nick or stress consideration of the untempered martensite will always result in poor weight control of the mult.

Flame cutting used as a primary method in one plant could not be fully evaluated since that plant was not in operation. Flame cutting, however, is used as a supplemental operation to separate the last mult from the billet where the Nick and Break is used. Flame cutting does give a little better weight control than Nick and Break because of the irregular and/or broken surface associated with nicked and broken mults. Control of kerf width in flame cutting is not as good as in sawing with resulting poorer weight control for flame cutting. Some waviness occurs on the face of cold sheared mults so that weight control of flame cut and cold sheared mults could be expected to be approximately equal.

2. Condition of Parted Surface

Sawing as a means of billet separation provides an excellent parted surface. In some instances where circular saws are used, a scoring or scribbing condition can be seen on the cut surface. This can easily be controlled and with existing processes, offers no problem. Sawing does, however, preclude the possibility of visually examining the mult parted surface for secondary pipes, cracks, holes, and spongy centers that might exist due to defective incoming steel. This can require, in some cases where there is a severe application, that micro etch of the ends of bar be accomplished to find defective incoming steel. Other techniques, such as ultrasonic inspection should provide a means of screening defective steel before billet separation ever takes place.

Cold shearing offers a satisfactory surface for hot cup-cold draw. Observation of sheared surfaces reveal that they are not usually truly flat but contain a leaf along the sheared surface. This leaf varies in magnitude usually not causing a production problem but the magnitude of the leaf can be controlled to some extent by good tool design and rugged shear press design. One plant improved their shearing operation consistently thru the purchase of a shear press specifically designed for their operation. Like the sawing operation, shearing precludes visual inspection of the parted surface for defective material.

Nick and Break offers the roughest and most irregular surface of all the billet separation techniques. This rough surface is reflected in the cavity of the forging. This irregularity oftentimes can lead to rejects due to cavity defects. Many attempts have been tried in the past to improve this surace. It has been found that surface condition is sensitive to undefined parameters of incoming steel. Steel conversion techniques such as casting, rolling, cooling, etc. are among some of the factors that are suspected of affecting broken surface quality. In the past when the broken surface is considered excessive by the buyer of the steel, the steel company is contacted and

usually adjustments are made at the mill such as controlling grain size, etc. , until the problem is alleviated. It has been found in some instances that ambient temperature affects the quality of the broken surface. Nick and Break does offer the opportunity to visually inspect each fracture surface for defective incoming steel.

Flame cutting offers a satisfactory surface for hot forge and heat treatment. The surface is usually relatively smooth with some scoring possible from the torch itself. Like sawing and cold shearing, visual examination of the surface cannot be used to detect defective incoming material.

3. Straightness of Parted Surface

Sawing offers a relatively straight parted surface varying in order of plus or minus one degree from the normal. Straightness is a desirable feature for several reasons. If a mult is suitably straight, it can be pushed thru and induction heated with mults lined up end to end. A straight surface can enhance the ensuing forming operation providing less misalignment force to the first forming punch thereby resulting in better concentricity which in turn leads to less metal removal and lower multiple starting weight.

Cold shearing provides a relatively straight surface usually not quite as good as sawing. The straightness is reported by the BUDD Co. study to vary within plus or minus two degrees ($\pm 2°$). Observation where sheared mults were being fed end to end in induction.heaters revealed occasionally a mult would tend to ride up because of its angular surface causing some scoring of the ceramic liner surrounding the induction coils. This was not considered a major production problem but does indicate that the process of shearing must be controlled when induction heating is employed. As in any forming process, the straighter the surface of the mult is to the norm the better the forming operation should be, given all other factors are equal.

Nick and Break offers the most uneven and most oblique surface of any parting method. Induction heating of nicked and broken mults was not observed and it is doubtful, from the observed condition of the broken surfaces, that induction heating could be used in the case where the broken surfaces are aligned end to end. If induction heating were to be employed, the mults would be aligned along their length or mill side. This obliquity contributes to greater weight variation and to some extent uneveness in length of the finish drawn forging. This, in turn, requires that additional material be added to the mult to assure that even the shortest drawn forging meets minimum length requirements.

Flame cutting provides a relatively straight surface as compared to Nick and Break. It is not as straight as sawing but with some control compares to cold shearing. It was observed that flame cutting was used in conjunction with Induction Heaters with the flame cut surfaces adjacent to each other while being pushed thru the coils.

4. Material Lost Due to Parting

Sawing, of course, results in a direct material loss due to the Kerf which is a function of the cutting blade width and set of the cutting teeth on the blade. In the case of the three and one-half inch round cornered square bar a minimum of two tenths of a pound (0.2 lb) is lost to kerf in each cut.

Cold shearing results in virtually no kerf or weight loss due to the nature of the process.

Nick and Break results in some metal loss, although very little, due to the nicking operation itself. Normally no metal is lost in the breaking operation.

Flame cutting results in a kerf one quarter inch or more.

In all cases, the last section of the billet that does not meet minimum mult length must be discarded.

In summary, evaluating the four techniques without consideration to other cost factors the following chart is presented, where 1 is considered the most acceptable and 4 is considered the least acceptable.

	Weight Control Variation	Surface Condition	Straight-ness	Material Loss
Sawing	1	1	1	3
Cold Shearing	2	2	2	1
Nick & Break	4	4	4	2
Flame Cutting	3	3	3	4

It should be noted that the above chart considers only the material lost in the billet separation method and does not consider other factors that might require higher mult weights such as obliquity, etc. When these are considered, the Nick and Break method appears to be the worst. Additional factors such as direct operating costs, floor space requirements, equipment costs, etc., should be taken into consideration in order to evaluate the cost effectiveness of the various methods of billet separation for specific applications.

D. STUDIES

Two programs have been conducted on billet separation by Frankford Arsenal. One study completed in 1971 evaluates a particular sawing technique using a Goellner Saw and the other is an on-going MM&T Program 5736358 titled, "Investigation of Hot Parting Approach to Billet Separation."

1. Goellner Metal Cut XII Saw Study

The Goellner Metal Cutt XII Saw has been tested at the Scranton AAP under the technical supervision of Frankford Arsenal. The results of this study may be found in the report titled, "Phase II Production Evaluation of New Sawing Concept" dated 24 August 1971.

Results of the test indicated that separation with this type of saw is competitive with nick and break. A total of 50,636 cuts were made on two grades of steel, 1061 6" RCS and 1046 5 1/4" RCS. These steels were used in the fabrication of the 175MM M437, and the 155MM M107 respectively.

Two types of installations were considered in determining the cost of billet separation by the Goellner Saw vs. Nick and Break. They were:

(1) A line dependent system which would feed each projectile line directly.

(2) A central system which would locate all saws or breakers in a centralized location from which billets would be fed to each manufacturing line as needed.

The cost comparison is as follows:

(1) Line Dependent System

	Nick & Break		Goellner Saw	
	175MM	155MM	175MM	155MM
Total Cost per Billet —	$.2110	$.1829	$.2172	$.1639

(2) Central System

	Nick & Break		Goellner Saw	
	175MM	155MM	175MM	155MM
Total Cost per Billet —	$.1270	$.1270	$.1399	$.1043

Additional benefits were also reported:

(1) The general quality of the forgings from sawed billets is superior to that of forgings fabricated from broken billets. Rejection rates for inspected forgings may be reducible by 40 to 46%. Emphasis is placed on the surface finishes; particularly in the forging cavity.

(2) Compared with the broken billets, the sawed billets with their clean, square end cause less wear in the forge tooling. Also, the sawed billets are easier and more economical to handle during heating.

(3) Sawing facilitates closer control of the billet length, and consequently, closer control of the billet weight than in the nick and break method. Accuracy of billet weight is ± 1/2 pound when cutting 6 inch RCS steel bar. Variations in cross sections of bars negates closer control. Another result is reduced trim scrap at the center and cutoff machining station.

Recommendations contained in the study indicate that the complete exploration of the Goellner Saw has not been achieved and further evaluations of the parting capabilities of the saw should be conducted utilizing other grades of steel.

2. Investigation of Hot Parting Billet Separation

Investigation of hot billet parting is currently being conducted by Frankford Arsenal under a PEM Project Number 5726358. A comparison of cold parting vs. hot parting is shown below:

Cold Parting

1. Convey billets to parting equipment
2. Part billets into mults
3. Convey mults to furnace
4. Heat mults
5. Convey hot mults to forge

Hot Parting

1. Convey billets to furnace (automatic loading)
2. Heat billet
3. Hot part mults
4. Convey hot mults to forge

The benefits to be derived from a hot parting system relate to improved manufacturing methods, savings from process simplification, reduced material handling by integrating the system, improved weight control, improved quality of parted surface, reduction in direct labor, etc. The manufacturing method can be improved from several viewpoints. For one, the system proposed is an integrated system where the cold billet is placed on an unscrambling table and is processed automatically thru the heater and shear press to the forging press system. Once the billet is unscrambled, it is automatically fed to a weighing platform. The billet is weighed at two points along

its length. The absolute values of the weight are fed into a simple computer. The computer assumes the cross section of the billet is uniform. The computer calculates the length of the billet, the number of mults to be sheared, the unit weight per unit length and feeds the output of this to the hot shear press adjustment device. This device corrects for the optimum mult length within each billet. Two approaches can be taken here. One is to average the extra length of the billet over the mults and the other is to shear the extra length of the mult prior to processing the rest of the billet thru the shear. It is believed the best approach is to average the extra billet length over the "M" number of mults obtained from the billet. This procedure eliminates one shearing operation per billet and will probably, based on statistical analysis using a normal distribution for excess billet, permit us to program the computer to "aim" at a lower mean mult weight.

It is anticipated that since a clear parted surface is introduced to the forging press, the forging tools will last longer due to the absence of scaling which tends to wear punch tips out. This in turn will increase the availability of our forge press system and should reduce down time for replacing punch tips. The shear press replacing saws or conventional nick and break operations is a process simplification in itself requiring less floor space and direct labor. Process simplification in the hot shear system will occur from the viewpoint that when the forge press is down for a routine adjustment such as changing punch tips, knockouts, etc., a signal will be fed back either manually or electronically to the induction heat-shear press system which will go into an automatic "hold" operation. The billet will be moved back and forth to maintain temperature and can be held this way for fifteen minutes. In the event the forge is down unexpectedly for more than fifteen minutes, the billet is automatically backed out of the induction heater and dropped in a cradle for reheating later on. All of these features discussed above are in existence today and are being used commercially. A further advantage of this system is that the thermal efficiency of induction heating here is in the order of fifty percent (50%). More will be reported on this MM&T program under its own project report.

E. CONCLUSIONS

Careful examination of the present methods of billet separation in the projectile MPTS plants visited, clearly indicate that significant improvements can be made.

Automatic nick and break on mechanical presses is fast and inexpensive, but will not offer close weight control with square ends and produces cavity defects. Cold shearing, flame cutting and sawing are alternatives, but each has limitations as mentioned above.

Based on the study to date, hot shearing appears to be the best known method of billet parting and is gradually being introduced to the domestic forging industries.

F. RECOMMENDATIONS

Based on the preliminary findings of Frankford Arsenal's investigation of hot parting, hot shearing is recommended for future modernization of artillery metal parts manufacturing plants for the following major end items: 105MM M1, 105MM XM710, 155MM M107, 155MM M483 and 8 Inch XM711.

Further examination of the Goellner metal cut saw is recommended for possible application as a back-up operation for hot shearing or as a means of cutting the last billet off the bar.

G. REMARKS

Current planning indicates that higher carbon and alloy steels will be utilized for production of future projectile metal parts. Because of low production rates, surface hardening, and possible cracking, it appears that neither sawing nor flame cutting will be applicable to future production.

SECTION TWO

FORMING

A. INTRODUCTION

Forming is the process where the mult previously separated from the billet is converted into a bottle shaped forging or extrusion. Forming may be accomplished at ambient temperature or at elevated temperatures.

B. PROJECTILE MANUFACTURING PRACTICE

All of the plants surveyed used hot forging as a basic process. Three of the plants using the hot cup-cold draw process use a cold draw or forward extrusion at ambient temperature to obtain a final length. The following is a list of the nine plants visited and their forming processes:

1. Burlington AAP — Hot cup-cold draw - 81MM M374 - (AISI 1340 Steel - 2 1/2" RD)
2. Gateway AAP — Hot forge-heat treat - 175MM M437 - (AISI 1062 Steel - 6" RCS)
3. Louisiana AAP — Hot forge-heat treat - 155MM M107 - (AISI 1060 Steel - 5 1/4" RCS)
4. National Presto — Hot cup-cold draw - 105MM M1 - (AISI 1018 Steel - 3 1/2" RCS)
5. Riverbank AAP — Hot cup-cold draw - 81MM M374 - (AISI 1340 Steel - 3" RD)
6. St. Louis AAP — Hot forge-heat treat - 105MM M1 - (AISI 1045 Steel - 4" RCS)
7. Scranton AAP — Hot forge-heat treat - 155MM M107 - (AISI 1060 Steel - 5 1/4" RCS)
8. Twin Cities AAP — Hot forge-heat treat - 155MM M107 - (AISI 1060 Steel - 6" RCS)
9. U.S. Steel Berwick — Hot cup-cold draw - 8 Inch M106 - (AISI 1018 Steel- 7 3/8" RCS)

It was observed early in the survey that a very strong forming-equipment preference existed in the projectile manufacturing plants. Observation, for instance, revealed

that most of the plants used hydraulic presses in lieu of mechanical presses. It was also observed that without exception, all draw operations whether performed hot or cold, employed hydraulic presses. It was difficult to determine how the commitment to hydraulic presses occurred in the past, but the reason given for the hydraulic presses used for the draw operation was the long stroke required for a draw operation.

With regard to the forging operation, the use of mechanical presses existed in at least one plant where an automatic three station press was being used to manufacture the forging for the 105MM M1 projectile. This press was observed to operate at ten strokes per minute performing block, cabbage and pierce with a minimum number of personnel required for its operation. On the other hand, separate hydraulic presses, one for cabbage, one for pierce and one for draw were observed being used to manufacture the 155MM M107 projectile forging at the maximum rate of three strokes a minute with a maximum number of personnel operating, feeding, and moving projectiles to the next operation.

Virtually, all of the plants visited utilize an oil-graphite mixture for forge lubrication. The resultant smoke and oil vapors contribute to both fire hazards and poor housekeeping conditions within the plants and are a source of air pollution when exhausted into the atmosphere.

One manufacturer has successfully utilized a graphite suspended in water lubricant for his cabbage and extrude operations with a significant reduction in effluents. However, an oil-graphite lubricant was required at the coin operation due to an inability of lubricating the hot pierced part with a water-graphite mixture. A second manufacturer has reported success in lubricating his cabbage and draw tooling with water-base lubricant. Water-base lubricant was also used successfully on the pierce punch. However, attempts to use it on the die pot met with failure. The manufacturer has projected that water-based lubricants will be used on all future production.

C. CRITIQUE

Discussion with personnel as to how these differences in operating forging lines came about led to various ideas but nothing conclusive. Literature surveys clearly revealed that considerable information already existed on forming, forming tonnage-displacement curves, etc., but practically none of this information was being applied. One contractor is now successfully operating a mechanical forge press that performs cabbage and pierce operations in tandem with a hydraulic draw press. The mechanical forge press cycles at six strokes a minute yielding three forgings a minute since it performs two operations, cabbage and pierce. The pierced forging is automatically fed from the forge press to the hydraulic draw press which can accept and process automatically three forgings per minute. This system represents a significant advancement in forging compared to any other system observed in projectile metal parts plants.

The Budd Co. Study reports that in addition to faster cycle rates, mechanical presses offer other distinct advantages over hydraulic presses:

1. Lower initial cost and less complex maintenance
2. Less tool wear because of less contact time with the part
3. Shut-down and start-up is relatively simple

It became apparent during the course of the plant surveys that the advantages of mechanical presses in lieu of hydraulic were only beginning to be recognized and could be further exploited. As a result, the modernization of the hot forging process for the 105MM M1 projectile originally intended for St. Louis AAP, but to be directed to Lone Star will utilize a transfer press capable of accomplishing the size, cabbage, pierce and draw of the forging operation in one press. The new design press is a four stage 2000 ton mechanical press with the unique feature of having a 24 inch hydraulic extender incorporated in the slide to give the additional stroke necessary to draw the projectile. The press is designed with sufficient capacity and stroke to forge both the conventional 105MM M1 projectile and projectiles upt to five inches longer.

The purchase of this press represents a significant reduction in equipment cost. The functional specification to which the press equipment was purchased would normally require five three station mechanical presses to perform the size, cabbage, and pierce operation and ten hydraulic presses to perform the draw to meet the designated production output.

Five mechanical presses combining the draw would accomplish the same production output with the elimination of the initial cost of ten hydraulic presses (4.58$\overline{M}$, FY72$) with a slight increase in cost in the mechanical presses (1.88$\overline{M}$, FY72$).

In addition to the cost avoidance attributable to the purchase of less equipment, direct labor and floor space are significantly reduced when the new forging concept is adopted; however, because of the production rates and the unique concept, some risk is involved.

Several comments relative to forming were offered by the Budd Co. as regards possible alternatives to both the present methods of forming and the equipment used:

The Budd Co. Study reports that the Multilink* press recently marketed by E. W. Bliss, offers a mechanical operation with a press motion curve having many of the desirable characteristics of a hydraulic press. The advantages claimed for this press are: reduction in press size, reduced noise levels, extended tool life and higher production rates relative to conventional mechanical presses.

*Also known as "4 bar linkage" or "power bar"

Two such presses have recently been installed in a projectile metal parts plant. The presses were used to nose the 81MM M374. Approximately twice the production rate of the previously used hydraulic presses was realized.

As regards powder metal forgings, the Budd Co. survey indicates that the activity in hot forging powder metal preforms is increasing. The advantages claimed are:

1. Up to 50% reduction in the amount of material used.
2. The obtainment of excellent detail and dimensional control thus eliminating machining operations.
3. The development of more uniform mechanical properties throughout a part.
4. Lower forging temperatures (1400°F to 1800°F) vs. 2200°F for normal hot forging.

In forging lubrication practices, it was reported that graphite particles suspended in oil is the most common lubrication for hot forging steel. However, an all-out effort to develop alternative lubricants, such as graphite suspended in water is underway. Glass suspended in alcohol and other vehicles is being employed in industry to an increasing level as a lubricant. Ceramic coatings are also used to some extent but the cost was considered too high for use in ordinary steel forging operations. The Budd Co. reported that lubrication for forging is still an art and further evaluation of lubrication systems is necessary.

An additional alternative to the forming methods used in projectile manufacture was suggested by Frankford Arsenal engineers. The process suggested is squeeze casting. This process consists of metering a known volume of molten metal into a bottom die cavity, allowing it to cool below the liquidus, then applying pressure by means of a top punch and allowing the solidification to go to completion under high pressure. This is a process intermediate between casting and forging. It is claimed that squeeze casting can be used for making parts of greater complexity that forgings and of better quality than castings.

The rest of this section will discuss the information available to date, which is considerable, and attempt to demonstrate how it can be successfully applied to the manufacture of future forgings with modern equipment. Further, recent advancements in technology such as mathematical modeling will permit the achievement of optimum equipment-tool design requirements. The application of these techniques will result in procurement of efficient equipment giving high reliability, low operating cost, low maintenance and layaway cost and large reduction in manpower requirements over what is presently being used.

D. STUDIES

Perhaps the most important observation in this investigation was that much improvement could be made in the area of forming through the application of currently available techniques. As an example of what is involved, the following areas will be covered in the remainder of this section.

I. Mathematical Modeling of the Draw Operation

This section discusses the application of new techniques to the design and optimization of a particular forming operation — the Draw.

II. Solid State Switching

The discussion here revolves around recent improvements in solid state circuitry and considers the specific application in projectile forming plants.

III. Warm Forming Study

This discussion considers future problems that can be expected as alloy steels are introduced into the projectile plants which is expected in the late seventies or early eighties. An attempt is made to consider the application of certain observations made in the Frankford Arsenal Forge Shop and Machining areas.

IV. Nosing Studies

A detailed application of existing information is reviewed which demonstrates the unique application to forming — equipment relationship. Already, this technique is being used for equipment specifications. Extension of these techniques for future families of ammunition are discussed and improvements and refinements in this technique are recommended.

V. Mechanical Press Studies

The application of mechanical presses requires significantly better understanding of the forming-press relationship than when hydraulic presses are used. A hydraulic press can exert its rated tonnage for the full length of its stroke whereas a mechanical press exerts its tonnage at only one half inch from the bottom of its stroke. Uncertainities regarding the capabilities of mechanical presses in long work stroke applications may have been the single, most influential reason that hydraulic presses were purchased to such an extent in the past. This section discusses the application of mechanical presses to existing forming operations and clearly indicates that sufficient technology exists at this time to purchase mechanical presses in lieu of hydraulic presses when the specific forming requirements are known.

VI. Hot Tension Testing of Steels

This section provides the information needed to accurately predict the hot tension strength of carbon and alloy steels. Although other literature exists that suggests forging strengths of various steels at elevated temperatures, the data contained here is considered the most reliable for forging and is considered unique to this program. This information permits reasonably accurate predictions of load-displacement requirements for forming, thereby permitting the purchase of mechanical presses where desired.

VII. Tool Design

The tool design observed in various plants is significantly different. Back in 1943, Trinks suggested the application of contour tooling. In 1957, three forge plants in this country making the 155MM projectile were successfully using contour tooling. They were Rudisill Foundry, Englander and Rheem Mfg. Co. Because of the proprietary aspects of the tooling, the details were never publicly revealed. One plant in operation today is successfully applying similar techniques.

Since the cost of raw material contributes to over twenty-five percent of the cost in a unit item, the need to reduce steel requirements in the mult can never be understated. This section attempts to discuss what is technically possible at this time. It should be pointed out that it is even more feasible today with modern forging equipment than it was in 1957.

1. Mathematical Modeling of the Draw Operation

In all methods of artillery manufacture, the cold or hot drawing process represents the most important step of the forging operation. In the drawing process, the wall thickness of the projectile is reduced while the internal diameter is kept almost constant. A very significant aspect of the process is that the mandrel and the drawn projectile have the same speed at the exit from the die. This prevents disengagement of the punch from the base of the cavity and allows positive control of shell datum geometry.

Mathematical modeling of the draw operation was conducted under this project through the joint efforts of Frankford Arsenal and Battelle Columbus Laboratories under Contract No. DAAA25-74-C0557. The overall objective of the program was to develop a sound and reliable mathematical model and computer programs capable of optimizing the drawing process for artillery metal parts.

The mathematical model was based on the analysis of deformation mechanics and includes: (a) properties of projectile, die and punch materials, (b) process variables such as drawing speed, shell temperature and lubrication, and (c) die configurations, including conical and curved dies. The model was computerized so

that it is now possible to: (a) predict potential material failure (such as punch through) and (b) optimize die configurations to obtain minimum draw force and stresses.

The detailed methods of analysis and the complete results of this study may be found in the reports titled: "Development of a Mathematical Model and Computer Programs Capable of Optimizing the Drawing Process for Actual Artillery Shell and Cartridge Cases" and "Mathematical Modeling of Artillery Shell Drawing." These reports are found under separate cover attached to this report.

2. Solid State Switching Studies

An investigation to determine if solid state switching could be used to advantage in projectile metal parts manufacture was conducted under this project. This study was undertaken to assure that the machine tools and presses being purchased for the modernization of our artillery metal parts utilized the most reliable switching controls available to date. All of the switching components in use in all our plants today are of the classic mechanical relay type. Due to the environment in which they are placed, a great deal of maintenance is required to keep them in working order (for example, at LAAP, the switching panels, even though they are enclosed in hermetically sealed cabinets, have to be cleaned once a week to keep the contact points clean of the air born scale and oil produced by the forge operations).

The solid state electronics industry was contacted in order to determine if solid state switching devices had reached the state-of-the-art where they could be used in lieu of conventional relay panels. The industries contacted were: General Electric, Westinghouse and Allen-Bradley, all of which had developed industrial type solid state switching devices.

As a result of conversations held with the solid state switching industries, Frankford Arsenal engineers recommended that solid state switching be procured with the Erie Forge presses to be used in the manufacture of the 105MM M107 projectile.

At Louisiana AAP, the GE Logitrol System was procured with the presses. Try-out for the first press system incorporating logitrol was accomplished in the latter part of 1975.

The advantages expected to be gained from the use of solid state switching are:

a. Less downtime for the press electronics with decreased time to repair. When electrical failure occurs, the normal method of trouble shooting conventional relay panels for a press is time consuming.

Solid state switching devices are capable of displaying the status of their control circuits. This allows a shop electrician to quickly spot a malfunctioning component. Once the component is identified, it can be quickly repaired by simply replacing the plug in module containing the failed part.

b. Added production capability can be built into a press system. Normally, when either the cabbage or pierce press is not functioning; the forge line is down. However, the cabbage and pierce presses being purchased for LAAP are capable of cabbage and pierce on the same press using shuttle punches and a common die. Thus if a pierce press failed, the cabbage press will be capable of performing both the cabbage and pierce operations. If conventional mechanical relays were used to control the press; a time consuming rewiring would be required to change from a cabbage to a cabbage and pierce operation. The programmable solid state switching unit purchased for these presses is capable of quickly changing to a cabbage and pierce mode by re-programming the switching logic through either a portable key board or telephone line to a master computer. This flexibility allows the forge systems to be rapidly modified; assuring a minimum loss of production effort.

c. Less floor space is needed when solid state circuitry is used in lieu of conventional relays. A good example of this is the floor space required by the mechanical relay panels for the four station Bliss press recently purchased for St. Louis. Forty linear feet of relay panels are required. If solid state switching is used, only five linear feet of floor space would be needed.

d. Preventive maintenance is reduced. Solid state circuitry has no moving parts or exposed contact points as are found in mechanical relay panels which are subject to corrosion and deterioration requiring weekly cleaning.

e. The total installed and operating cost of solid state controlled manufacturing equipment may be lower than that of conventional relay controlled equipment. Conversations with Erie Press personnel indicate that while the initial hardware cost of solid state devices is higher than mechanical devices, the installation and try-out costs are significantly lower. This may result in a lower total cost to the buyer.

Some unknown factors and disadvantages do exist with solid state circuitry:

a. Lay away and storage life is unknown. The integrated circuitry used in solid state switching was not in existence until a few years ago, and no equipment using these switches has been laid away. Thus no data relative to storage life is available.

b. The availability of future replacement parts is unknown. The solid state electronics technology is changing so rapidly that any system purchased today may be outmoded in a few years and the replacement parts which utilize an outmoded technology may not be available.

It must be noted that the above uncertainties are unique to artillery metal parts production in that commercial producers who purchase solid state controlled equipment put it to immediate use and will probably wear out the equipment before the switching circuitry becomes obsolete; however, the Government may purchase equipment and not use it for five or ten years.

3. Warm Forming Study

When processing a high fragmentation steel designated HF-1 steel into artillery projectiles, a spheroidize operation is required after the hot forming operations in order to facilitate the rough machining operation. This study was initiated to determine if the spheroidize operation could be eliminated. Spheroidizing requires furnace equipment that is large and costly and adds to the production cost of a projectile because of the heating cycle required.

The basis for this study evolved during the production engineering of the 105MM M548 rocket assisted warhead from HF-1 steel conducted at Frankford Arsenal. Due to the location of the equipment, it was necessary to deviate from the normal HFHT process (in that after the pierce operation, the forging was cooled and reheated to a lower than normal temperature for the draw operation). It was observed that some forgings rough machined satisfactorily without a spheroidize anneal. Metallurgical examination of these forgings indicated that there were no massive carbides in the microstructure as in the instance of the non-spheroidized forgings in 105MM M1 projectiles made at AMMRC prior to the M548 encounter. At these lower temperatures, carbides normally precipitate at austenitic grain boundaries to form a continuous net work. However, if deformation of the austenitic grains occurs at the same time a continuous net work cannot grow and the carbides are more dispersed.

To verify this theory, an experiment was constructed by Frankford Arsenal and performed at National Presto Industries under this project to determine if a relationship existed between warm drawing and machining of HF-1 steel. 105MM M1 forgings manufactured from HF-1 steel were warm drawn by varying the draw temperatures from 1325°F to 1525°F. The sequence of operations was:

1. Saw Bar
2. Heat Billet to 2000°F
3. Size
4. Cabbage
5. Pierce
6. Cool to Specified Temperature under Study (1325°F to 1525°F)
7. Draw

8. Cool to Room Temperature

9. Rough Machine

Machinability tests were run and it was found that tool life was significantly improved. The optimum warm temperature for drawing HF-1 steel was found to be 1425°F (See Figure 1).

In order to extend the information gained in the above study, 1000 15MM M107 projectiles were manufactured at Louisiana AAP. The forgings were drawn at 1425°F and successfully rough turned without benefit of a spheroidize anneal.

In order to validate the results of this study, it is necessary to apply the warm drawing technique to a larger number of projectiles. In order to achieve this, a program has been submitted to manufacture thirty thousand (30,000) 155MM M107 projectiles from HF-1 Steel using warm forming techniques. The proposed sequence of operation is:

1. Nick Bar
2. Break Bar
3. Heat Billet to a temperature to be determined
4. Cabbage
5. Pierce
6. Draw at 1425°F
7. Rough Machine

The mult will be heated to a lower temperature in order that the pierced forging will reach the draw die at 1425°F.

If the program is successful, it will be confirmed that a spheroidize operation is not required to rough machine projectiles manufactured from HF-1 Steel. This would result in significant cost savings in equipment, floor space, direct and indirect labor, fuel and energy.

4. <u>Nosing Studies</u>

Nosing of conventional artillery projectiles is presently accomplished in a hydraulic press in one hit at approximately 1600°F. Very little practical information is available regarding the capacities of presses used for the forming of shell noses.

The objective of this study was to develop the means to: (1) Determine the force required, at any given stroke position, to nose a particular projectile design, and

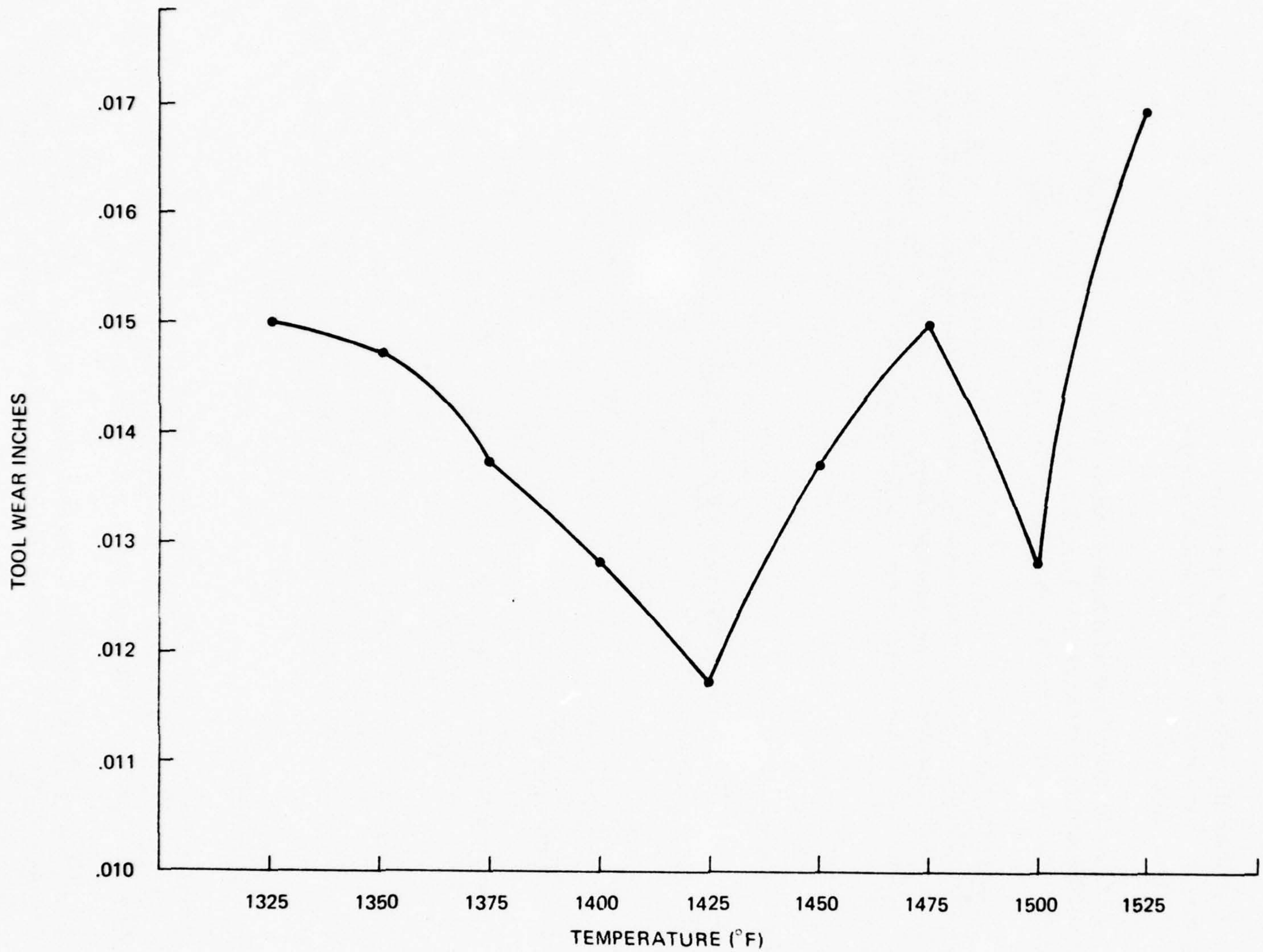


Figure 1 - Warm Forming Study

(2) Determine the buckling strength of a projectile during nosing in order to forecast the number of hits required.

Two projectile geometries were used as vehicles for this study: the 155MM M107 and the 155MM XM708. These projectiles were selected in order to support the modernization effort at Scranton AAP and Twin Cities AAP, where presses capable of nosing the 155MM M107 with the added capability of nosing the 155MM XM708 were required. A load vs stroke curve was needed for each projectile design in order to illustrate to the press manufacturer, the tonnages required along the work stroke. Furthermore the buckling strength of the projectiles during nosing was required to determine the numebr of hits required.

A literature search revealed that a mathematical method of determining nosing forces had been developed and published under the title "Plastic States of Stress in Curved Shells: The Forces Requires for Forging of the Nose of High Explosive Shells" by A. Nadai, Dec. 31, 1943. The methods described in this report were utilized to determine the tonnages required to nose the M107 and XM708 Projectiles. The following demonstrates the methods used:

a. Force required to nose the 155MM M107 and XM708 Projectiles.

The following function is found in the Nadai Report:

$$(1) \quad P = \frac{6.28\ Rhs\ (\cos 2f - e^{f \tan f} \cos 3f)}{2000}$$

where P = Force in Tons

R = Radius of the mean meridian circle of the shell nose

h = wall thickness

s = compression yield stress

f = friction angle

Applying the above equation to the 155MM M107 nosing configurations yields:

$$(2) \quad P = \frac{(6.28)\ (65.1581)\ h\ (75,000)\ (\cos 2f - e^{f \tan f} \cos 3f)}{2000}$$

where h and f can be expressed as functions of the press stroke.

Applying the values of h and f for various stroke position yields:

Press Stroke In. above B.D.C.*	h Inches	f Degrees	P Tons	P (30% Safety) Tons
10.61	.559	.433	.858	1.12
10.00	.567	1.62	4.26	5.54
9.00	.584	1.98	16.2	21.0
8.00	.599	2.93	21.4	27.9
7.00	.616	3.88	40	52.1
6.00	.632	4.83	76	99.5
5.00	.649	5.77	119	154
4.00	.665	6.72	166	215
3.00	.681	7.65	237	308
2.00	.698	8.58	341	443
1.00	.714	9.53	466	607
.5	.724	10.0	521	678

When applied to the 155MM XM708 equation (1) becomes

$$(3)\quad P = \frac{(6.28)\ (114.8135)H\ (120{,}000\ (\cos 2f - e^{f \tan f} \cos 3f)}{2000}$$

which yields:

Press Stroke In. above B.D.C.	h Inches	f Degrees	P Tons	P (30% Safety) Tons
14.22	.371	.350	1.12	1.46
14.00	.374	.466	1.94	2.53
13.00	.382	1.00	7.76	10.10
12.00	.389	1.53	18.4	23.9
11.00	.397	2.05	33.1	43.1
10.00	.404	2.58	53.6	69.7
9.00	.412	3.10	78.5	102
8.00	.419	3.63	110	143
7.00	.427	4.15	146	190
6.00	.434	4.66	188	245
5.00	.442	5.20	238	309
4.00	.449	5.72	293	381
3.00	.456	6.23	355	461
2.00	.464	6.75	424	551
1.00	.471	7.28	502	653
.500	.473	7.53	540	701

*B.D.C. — Bottom Dead Center

The above results established the tonnage required at various stroke positions to nose the 155MM M107 and XM708 projectiles. An examination of the load-stroke curve shown in Figure 2 reveals that the load required for nosing the M107 is consistently lower than that of the XM708 for all stroke positions. Thus a press capable of nosing the XM708 would also be capable of nosing the M107 providing that buckling does not occur.

In order to determine if buckling would occur during nosing, the load values obtained above were compared with the theoretical buckling strength of the projectiles at all stroke positions. The theoretical buckling strength was determined by the "Timoshenko" method in the following manner:

b. Buckling strength in nosing the 155MM M107 and XM708 Projectiles:

The following formula is contained in "Theory of Elastic Stability" by S. Timoshenko, 1936:

$$(1)\quad S = \frac{EH}{R\sqrt{3(1-r^2)}}$$

where:

S = Stress necessary to cause buckling

E = Modulus of elasticity

H = Wall thickness

R = Radius of shell

r = Poisson's Ratio

When applied to the 155MM M107, equation (1) becomes:

$$(2)\quad S = \frac{(30 \times 10^6)\,H}{(65.158)\sqrt{3\,(1-.3^2)}}$$

By inserting the values of H utilized in equation (2) of paragraph a, the buckling strength vs stroke can be obtained:

Press Stroke In. Above B.D.C.	H Inches	S Tons/In^2	Safety Factor S/Load
10.61	.559	77.9	983
10.00	.567	79.0	201

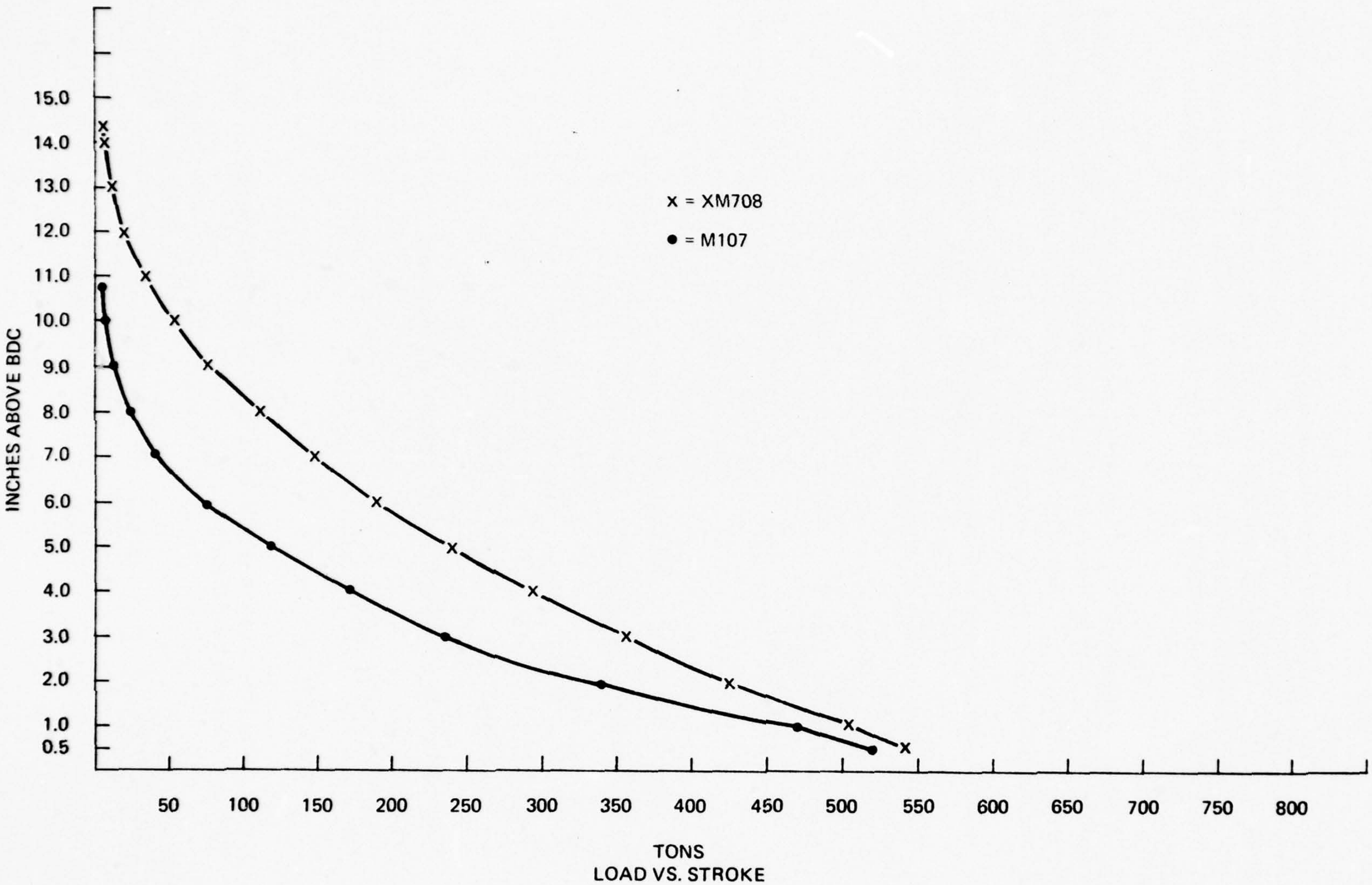


Figure 2 - Load vs. Stroke

Press Stroke In. Above B.D.C.	H Inches	S Tons/In^2	Safety Factor S/Load
9.00	.584	81.3	54.8
8.00	.599	83.6	42.7
7.00	.616	85.8	23.6
6.00	.632	88.1	12.7
5.00	.649	90.3	8.46
4.00	.665	92.6	6.24
3.00	.681	94.9	4.49
2.00	.698	97.2	3.21
1.00	.714	99.4	2.41
.50	.724	101.0	2.19

The safety factors listed above are obtained by dividing the buckling stresses by the nosing pressures obtained from equation (2) of paragraph a.

A safety factor greater than one (1.00) indicates that buckling will not occur during nosing.

Applying equation (1) to the 155MM XM708 yields:

$$(3)\quad S = \frac{(30 \text{ X } 10^6)H}{114.8135 \sqrt{3\,(1-.3^2)}}$$

Inserting the values of H used in equation (3) of paragraph a yields:

Press Stroke In. Above B.D.C.	H Inches	S Tons/In^2	Safety Factor S/Load
14.22	.371	29.3	245
14.00	.374	29.6	143
13.00	.382	30.2	36.8
12.00	.389	30.8	15.9
11.00	.397	30.6	8.82
10.00	.404	32.0	5.73
9.00	.412	32.6	4.00
8.00	.419	33.1	2.92
7.00	.427	33.8	2.25
6.00	.434	34.3	1.79
5.00	.442	34.9	1.45
4.00	.449	35.5	1.20
3.00	.456	36.1	1.01

Press Stroke In. Above B.D.C.	H Inches	S Tons/In^2	Safety Factor S/Load
2.00	.464	36.7	.867
1.00	.471	37.3	.747
.50	.473	37.4	.699

The above results indicate that buckling may occur at press stroke positions below three inches above B.D.C. This may necessitate the utilization of two hits to nose the 155MM XM708. Thus unless means are found to reduce the pressures required for nosing the XM708, consideration should be given to the fact that although it is possible to purchase presses with sufficient load-stroke capability of nosing both the M107 and XM 708, it may be necessary to purchase additional presses to avoid buckling of the XM708. Another possibility exists in that the same press may be used to nose the projectile in two hits with shuttling nosing dies. This would divide into two hits the total load needed and increase the projectile's resistance to buckling.

Additional studies are required to establish a more accurate means of predicting nosing forces and buckling. Means of determining the effects of such variables as *ram speeds, heat gradiants*, coefficients of friction, strain rates, and nosing temperatures must be undertaken.

It is essential for equipment purchase, plant layouts, and the manufacture of future projectiles to establish an accurate mathematical determination on the forming of shell noses. Basically, nosing is accomplished to a great degree by trial and error coupled with manufacturing experience. This could be eliminated if one could predict with reasonable accuracy the force needed to nose a projectile, the optimum tonnage press and the minimum number of hits necessary to prevent buckling. The new family of 155MM and 8 Inch Projectiles with long ogives and thin walls could pose a problem in manufacture, especially in nosing. The forces needed to nose these projectiles must be investigated in order to determine their compatibility with the current state-of-the-art of manufacturing techniques.

5. <u>Mechanical Press Studies</u>

In order to analyze mechanical press designs proposed for nosing the 155MM M107 and XM708 it was necessary to develop a method of determining load-stroke curves for various crank and slider press designs. Through a comparison of the load stroke curves developed in the nosing studies, it could be determined if a particular press had sufficient force at all working stroke positions to nose a particular projectile geometry.

The following method was developed to predict the displacement, velocity, acceleration, and available force at variable crank angles for mechanical presses.

a. Displacement, Velocity and Acceleration of Mechanical Presses (Crank and Slider):

Figure 3 illustrates the crank and linkage geometry of a mechanical press where:

L = Link Length

R = Crank Throw

X = Slide Displacement

The slide displacement can be written as:

$$(1)\quad x = R + L - R\cos\theta - L\cos\phi$$

where R and L are constants

Utilizing the law of sines and the identity: $\cos\phi = \sqrt{1-\sin^2\phi}$, allows equation (1) to be written as:

$$(2)\quad x = R(1-\cos\theta) + L\left[1-\left(1-\frac{R^2}{L^2}\sin^2\theta\right)^{1/2}\right]$$

Differentiation of equation (2) with respect to time (t) yields the velocity of the slide (V_s)

$$(3)\quad V_s = \frac{dx}{dt} = RW\left[\sin\theta + \left({}^{R}/_{2L}\right)\frac{\sin 2\theta}{\left(1-\frac{R^2}{L^2}\sin^2\theta\right)^{1/2}}\right]$$

where $w = \frac{d\theta}{dt}$ = RPM of Press multiplied by 2π

Differentiating equation (3) with respect to time yields the acceleration of the slide (A_s):

$$(4)\quad A_s = \frac{dV_s}{dt} = Rw^2\left[\frac{\cos\theta + \left({}^{R}/_{L}\right)\cos 2\theta + \left({}^{R}/_{L}\right)^3\sin^4\theta}{\left(1-\frac{R^2}{L^2}\sin^2\theta\right)^{3/2}}\right]$$

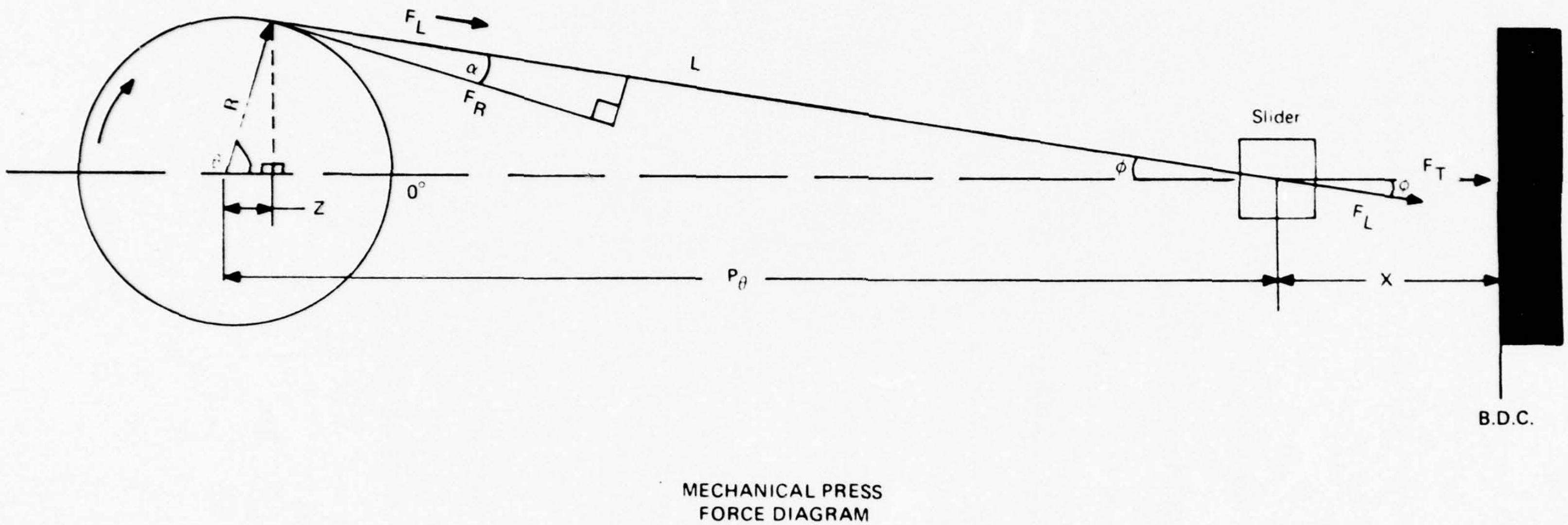


Figure 3 - Mechanical Press Force Diagram

Equations (2), (3) and (4) yield the displacement, velocity and acceleration of the slide at any point in the press cycle by utilizing the following parameters:

I Throw of the Crank

II Link Length

III RPM of the Press

b. Forces Developed by a Mechanical Press (Crank and Slider)

Figure 3 is a diagram of the forces generated by a mechanical press during the work portion of its stroke. The forces are defined as follows:

F_R = Force Perpendicular to Crank Throw

F_L = Force Along Link

F_T = Force Along Slide

Inspection of Figure 3 reveals:

(1) $F_T = F_L \cos \phi$

(2) $F_L = \dfrac{F_R}{\cos \alpha}$

$\therefore$ (3) $F_T = \dfrac{F_R \cos \phi}{\cos \alpha}$

In order to express F_T as a function of the crank angle θ, $\cos \phi$ and $\cos \alpha$ must be expressed as functions of θ.

From Figure 3:

$P_\theta + x = R + L$

$P_\theta = R + L - x$

$x = R + L - P_\theta$

From the law of sines:

$$\frac{P_\theta}{\text{Sin }(90^\circ + \alpha)} = \frac{L}{\text{Sin }\theta} = \frac{R}{\text{Sin }\phi} = \frac{R+L-x}{\text{Sin }(90^\circ + \alpha)}$$

Substituting the relation: Sin $(90^\circ + \alpha) =$ Cos α; yields:

$$\frac{R + L - x}{\cos \alpha} = \frac{L}{\text{Sin }\theta} = \frac{R}{\text{Sin }\phi}$$

$$\therefore \ (4)\quad \text{Cos }\alpha = \frac{(R + L - x)\text{ Sin }\theta}{L}$$

From Figure 3

$$\text{Cos }\phi = \frac{P_\theta - z}{L}$$

$$\text{Cos }\theta = \frac{z}{R}$$

$$\therefore \ (5)\quad \text{Cos }\phi = \frac{P_\theta - R\text{ Cos }\theta}{L}$$

Substituting Equations (4) and (5) into (3) yields:

$$F_T = F_R \frac{(P_\theta - R\text{ Cos }\theta)}{(\quad L \quad)} \frac{(\quad L \quad)}{(R+L-x)\text{ Sin }\theta)}$$

Or:

$$(6)\quad F_T = \frac{F_R\left(1 - \frac{R\text{ Cos }\theta}{R+L-x}\right)}{\text{Sin }\theta}$$

Substituting Equation (4) into (2) yields:

$$(7)\quad F_L = \frac{F_R\ L}{(R+L-x)\text{ Sin }\theta}$$

By utilizing equations (6) and (7) the force in the slider and link can be calculated at any point of crank angle provided the link length, crank throw and crank force of the press are known.

The link length and crank throw can be obtained from the press design. The crank force can be calculated in the manner shown in the following example. Example: Find the displacement, velocity, acceleration, force in link, and force in slider at 30° from B.D.C. of the press cycle for a press rated at 2000 tons 1/2" above B.D.C., crank throw of 24", link length of 116" and an RPM of 10 strokes/minute.

Displacement:

$$X = R(1-\cos\theta) + L\left[1-\left(1-\frac{R^2}{L^2}\sin^2\theta\right)^{1/2}\right]$$

$$X = 24\,(1-.86603) + 116\left[1-\left(1-\frac{24^2}{116^2}\times .25\right)^{1/2}\right]$$

$X = 3.8382$ inches from B.D.C.

Velocity:

$$V_S = RW\left[\sin\theta + \left(\frac{R}{2L}\,\frac{\sin 2\theta}{\left(1-\frac{R^2}{L^2}\sin^2\theta\right)^{1/2}}\right)\right]$$

$$V_S = (24)\,(2\pi)\,(10)\left[.5 + \left(\frac{24 \times .86603}{2 \times 116\,\left(1-\frac{24^2}{116^2}\times .25\right)^{1/2}}\right)\right]$$

$V_S = 889.81$ inches/minute or 14.83 inches/second

Acceleration:

$$A_S = RW^2\,\frac{\left(\cos\theta + \frac{R}{L}\cos 2\theta + \left(\frac{R}{L}\right)^3\sin^4\theta\right)}{\left(1-\left(\frac{R}{L}\right)^2\sin^2\theta\right)^{3/2}}$$

$$A_S = (24)\,(4\pi^2)\,(100)\left[\frac{.86603 + \frac{24}{116}\times .5 + \left(\frac{24}{116}\right)^3(.0625)}{\left(1-\left(\frac{24}{116}\right)^2\times .25\right)^{3/2}}\right]$$

$A_S = 93,403.85$ Inches/Minute^2 or $1,556.73$ inches/second^2

In order to evaluate the slide and link forces, it is necessary to determine the crank force (F_R). This can be accomplished by considering F_R constant throughout the press cycle and by utilizing the press rating supplied by the manufacturer (i.e. 2000 tons at 1/2 inch above B.D.C.). Equation (7) of paragraph b can then be written:

$$F_R = \frac{F_L}{L} (R + L - x) \sin\theta$$

From the Law of Cosines

$$\cos\theta = \frac{R^2 + P_\theta^{\,2} - L^2}{2R\,P_\theta}$$

Where $P_\theta = R + L - x$

$$\therefore \theta = \cos^{-1} \frac{R^2 + (R + L - x)^2 - L^2}{2R\,(R + L - x)}$$

At 1/2 inch above B.D.C.:

$$\theta = \cos^{-1} \frac{24^2\ (24 + 116 - 1/2)^2 - 116^2}{2 \times 24\ (24 + 116 - 1/2)}$$

Or $\theta = 10° \ 40'$

The crank force can then be determined:

$$F_R = \frac{2000}{116} (24 + 116 - 0.5)\ .18509$$

$F_R = 445.17$ Tons

Slide Force:

$$F_T = \frac{F_R \left(1 - \frac{R\cos\theta}{R + L - x}\right)}{\sin\theta}$$

$$F_T = \frac{445.17 \left(1 - \frac{(24) \cos 30^\circ}{24 + 116 - 3.8382}\right)}{\sin 30^\circ}$$

$$F_T = 754.42 \text{ Tons}$$

Link Force:

$$F_L = \frac{F_R \, L}{(R + L - x) \sin \theta}$$

$$F_L = \frac{(445.17)(116)}{(24 + 116 - 3.8382) \sin \theta}$$

$$F_L = 756.01 \text{ Tons}$$

The above examples illustrates the method of determining the displacement, velocity, acceleration, slide force, and link force at any location in the press cycle.

The equations developed above ban be programmed into a computer to generate a load vs. stroke curve for the entire cycle of a particular mechanical press. Through a comparison of the generated curve with the load vs. stroke curve required for a specific forming operation, it can now be determined if a particular mechanical press has sufficient tonnage along its stroke to perform a specific forming operation. The criteria for the comparison is that the tonnages generated by the press must equal or exceed the tonnage required at all working stroke positions for a particular forming operation.

The results of this study allow the option of utilizing mechanical presses in lieu of hydraulic presses in future modernization and equipment replacement programs.

6. Hot Tension Testing of Steels

Hot tension tests were performed on certain carbon, alloy and tool steels to obtain data about the tensile properties in order to evaluate the forgibility of the materials.

The testing was performed in 1970 in conjunction with the Bethlehem Steel Company. To help evaluate the forgibility of the materials, two (2) factors were investigated:

(1) The ductility of the steels at various temperatures on the basis of reduction in area of the hot tensile specimens.

(2) The ultimate hot strengths of the materials tested on the basis of the tonnage required to fracture the tensile specimens at various temperatures.

The following steels which are used in the forging of artillery projectiles were selected for hot tension testing:

AISI 52100

HF-1

AISI 1045

AISI 1095

PR-2

AISI 1012

AISI 06 Tool Steel

AISI 1340

The testing procedure was as follows:

(1) Two (2) specimens from each of the steels tested were pulled to fracture at 100° increments starting at 1300°F to 1800°F.

(2) Two (2) specimens from each of the steels tested were pulled to fracture at 50° increments starting at 1850°F to 2400°F.

(3) The broken tensile specimens were examined under an optical comparator to determine the new diameter of the tensile specimen.

(4) The load vs temperature and the percent reduction in area was tabulated (See Table 1-8)

(5) The load was plotted against the temperature as a measure of the energy to cause fracture and the percent reduction in area was plotted against temperature as a measure of ductility (See Figures 4-11).

Based on the results of this study, the specification of a safe heating temperature for maximum ductility of the steels tested was established (See Table 9). Heating above the specified temperature results in a loss of ductibility and forgibility attributed to damage of the steel (burning or incipient melting).

Foaming at the temperature of maximum ductility may result in the following benefits:

(1) Smaller and therefore less expensive presses may be utilized for a particular foaming operation.

Text continues on page 56

TABLE 1

HOT TENSILE TESTING RESULTS FOR AISI 52100

Temperature (°F)	Average Load (LBS)	Average Percent Reduction in Area
1300	4023	66.5
1400	2502	93.0
1500	2081	96.9
1600	1681	98.3
1700	1260	99.2
1800	1070	93.4
1900	952	99.7
2000	879	99.7
2100	820	95.9
2150	784	95.7
2200	744	82.2
2225	762	65.5
2250	667	54.6
2275	733	51.7
2300	496	22.2

TABLE 2

HOT TENSILE TESTING RESULTS FOR HF-1

Temperature (°F)	Average Load (LBS)	Average Percent Reduction in Area
1300	3647	81.5
1400	2336	93.4
1500	2021	95.7
1600	1629	97.3
1700	1304	98.2
1800	1158	98.7
1900	1055	96.4
1950	930	99.5
2000	886	98.3
2050	827	99.6
2100	820	99.1
2125	806	98.9

Table 2. Hot Tensile Testing Results for HF-1 (cont)

Temperature (°F)	Average Load (LBS)	Average Percent Reduction in Area
2150	776	88.0
2175	762	93.3
2200	498	17.9

TABLE 3

HOT TENSILE TESTING RESULTS FOR AISI 1045

Temperature (°F)	Average Load (LBS)	Average Percent Reduction in Area
1300	2000	94.2
1400	1790	96.0
1500	1260	98.0
1600	1230	98.0
1700	1030	99.0
1850	890	99.0
1900	750	99.5
2000	710	99.5
2150	660	98.5
2250	620	99.25
2300	590	94.0
2325	590	77.0
2350	580	86.8
2375	660	86.8
2400	590	40.0
2425	500	22.5
2450	290	45.2

TABLE 4

HOT TENSILE TESTING RESULTS FOR AISI 1095

Temperature (°F)	Average Load (LBS)	Average Percent Reduction in Area
1300	2082	87.6
1400	1952	90.3
1500	1888	95.0
1600	1659	97.4
1700	1209	97.3
1800	1143	99.4
1900	1004	99.5
2000	849	99.8
2100	762	83.8
2150	733	89.5
2200	616	37.3
2225	708	56.3
2250	535	18.2

TABLE 5

HOT TENSILE TESTING RESULTS FOR PR-II

Temperature (°F)	Average Load (LBS)	Average Percent Reduction in Area
1600	1780	90.5
1800	1355	97.5
2000	996	99.7
2100	894	99.7
2200	806	98.5
2250	747	93.0
2275	746	90.7
2300	733	64.6
2375	454	17.6
2400	483	17.6

TABLE 6

HOT TENSILE TESTING RESULTS FOR AISI 1012

Temperature (°F)	Average Load (LBS)	Average Percent Reduction in Area
1300	1607	93.7
1400	1363	97.5
1500	1327	96.4
1600	1282	98.0
1700	1157	98.2
1800	1026	98.6
1850	974	98.9
1900	908	96.4
1950	879	99.3
2000	777	99.4
2025	767	98.2
2050	769	99.5
2100	733	99.8
2150	689	96.2
2200	667	99.8
2250	674	99.4
2300	630	93.5
2350	615	89.6
2400	615	94.0
2500	601	81.2
2600	454	13.1

TABLE 7

HOT TENSILE TESTING RESULTS FOR AISI 06

Temperature (°F)	Average Load (LBS)	Average Percent Reduction in Area
1300	3049	71.16
1400	2587	79.3
1500	2154	81.9
1600	1814	81.1
1700	1466	84.8

Table 7. Hot Tensile Testing Results for AISI 06 (cont)

Temperature (°F)	Average Load (LBS)	Average Percent Reduction in Area
1800	1172	84.6
1850	1121	86.4
1900	982	90.4
1950	952	90.1
2000	849	81.4
2025	879	77.0
2050	835	72.0
2075	842	26.2
2100	674	11.5

TABLE 8

HOT TENSILE TESTING RESULTS FOR AISI 1340

Temperature (°F)	Average Load (LBS)	Average Percent Reduction in Area
1300	2375	84.8
1500	1730	93.9
1700	1297	96.8
1900	908	98.7
2100	726	99.6
2200	718	99.4
2250	674	95.7
2300	659	96.6
2350	652	98.4
2400	645	87.9
2450	454	20.4

Forming at the temperature of maximum ductility may result in the following benefits:

(1) Smaller and therefore less expensive presses may be utilized for a particular forming operation.

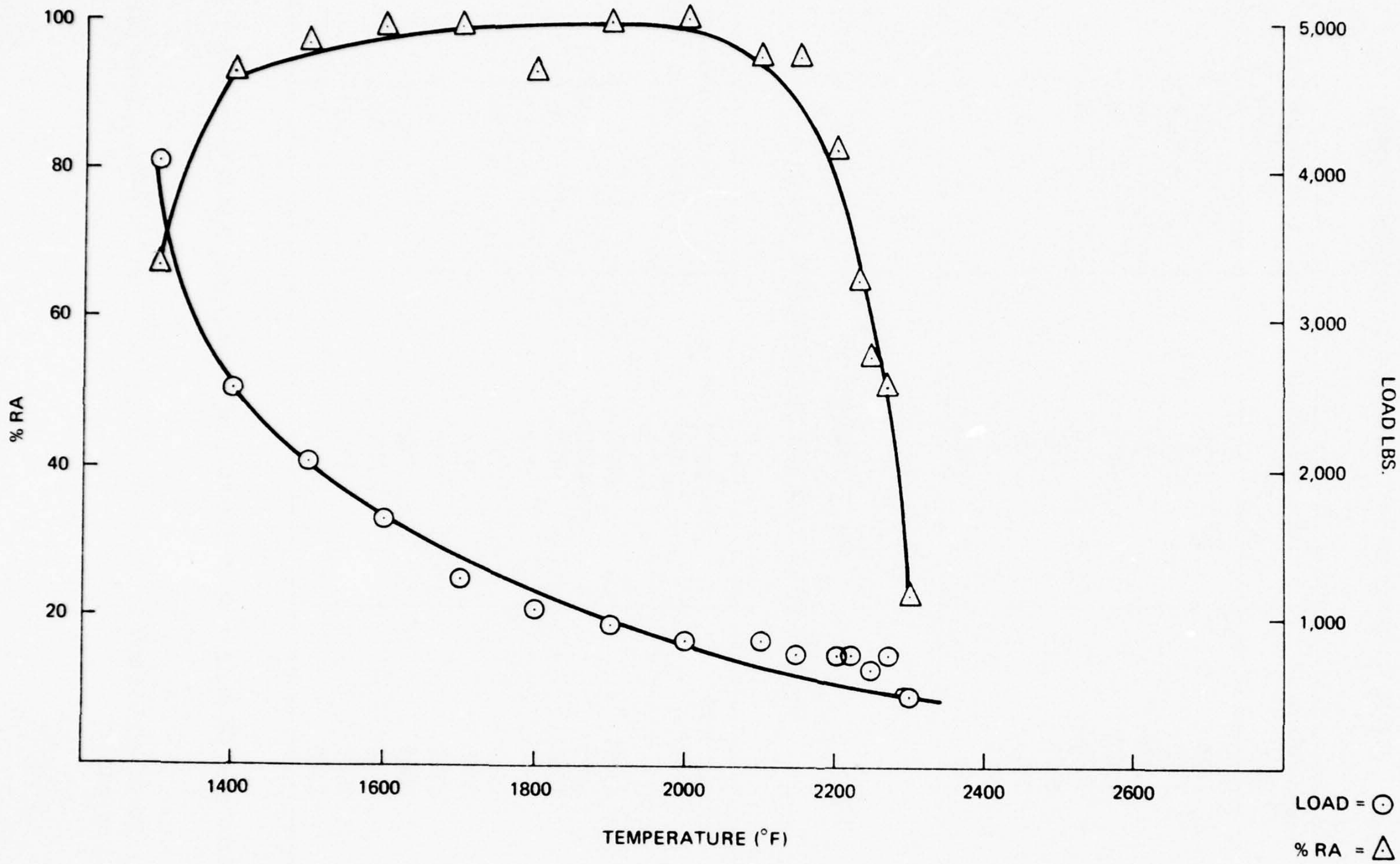


Figure 4 - AISI 52100

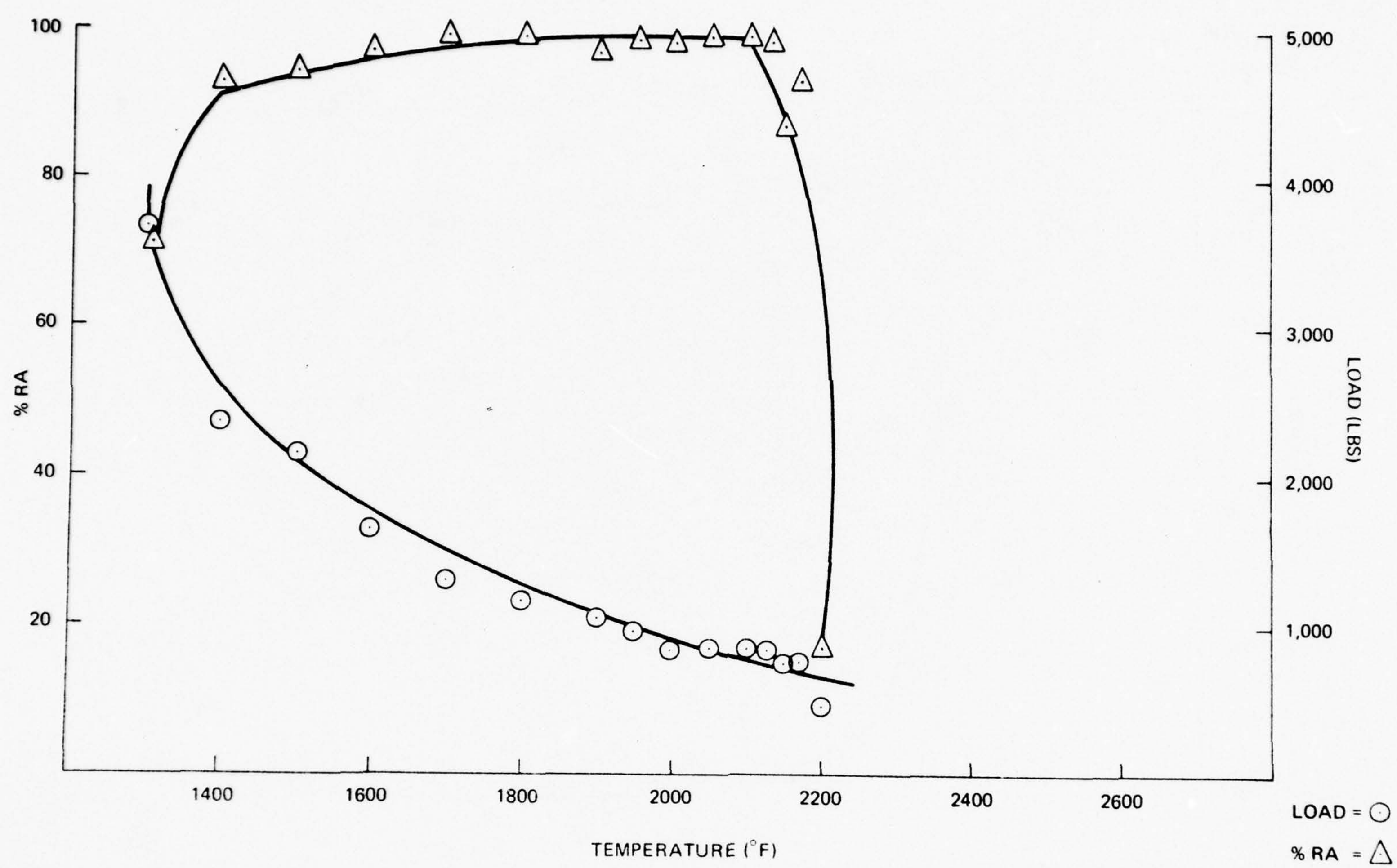

100
80
60
40
20
% RA
5,000
4,000
3,000
2,000
1,000
LOAD (LBS)
1400
1600
1800
2000
2200
2400
2600
TEMPERATURE (°F)
LOAD = ⊙
% RA = △

Figure 5 - HF-1

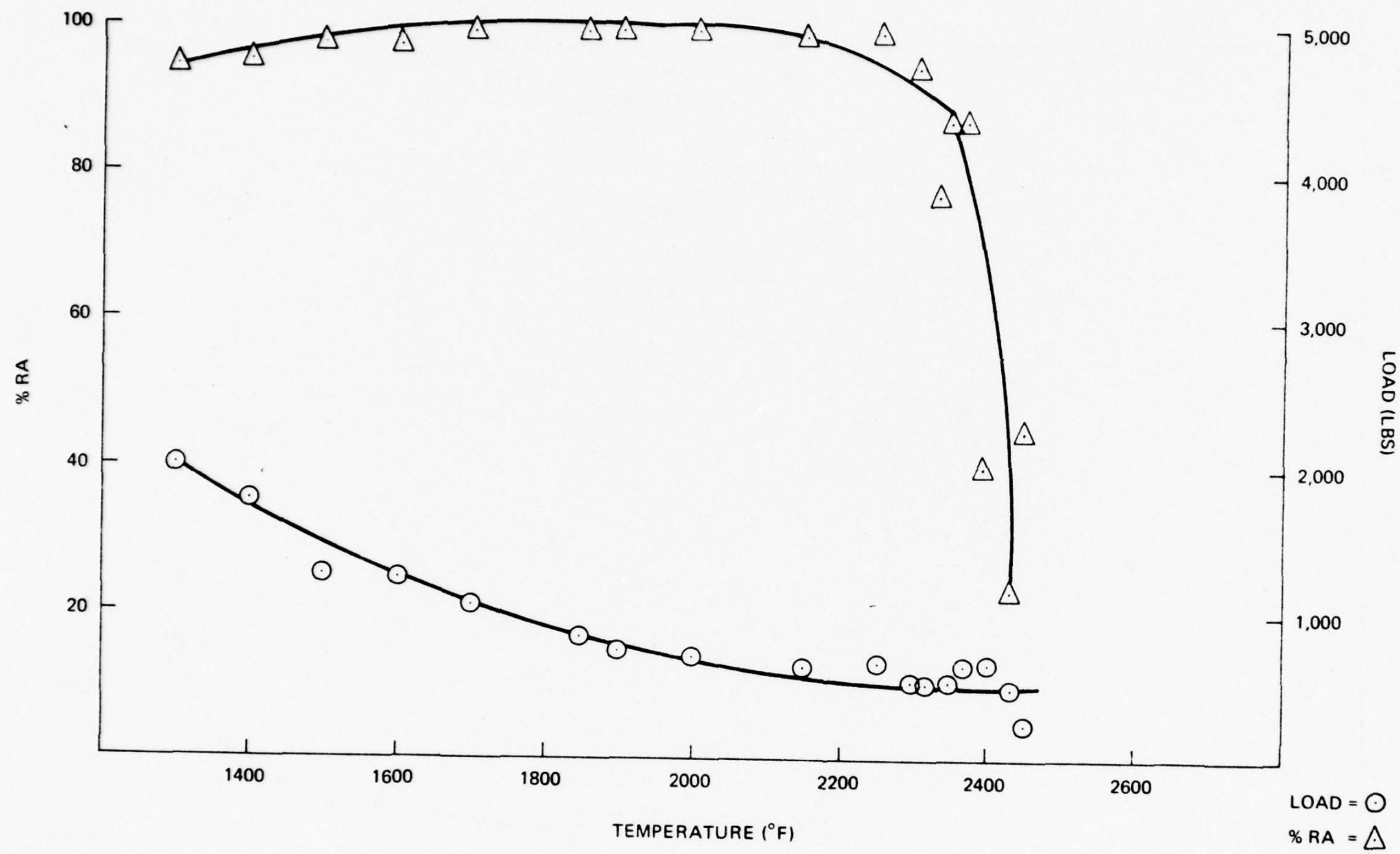


Figure 6 - AISI 1045

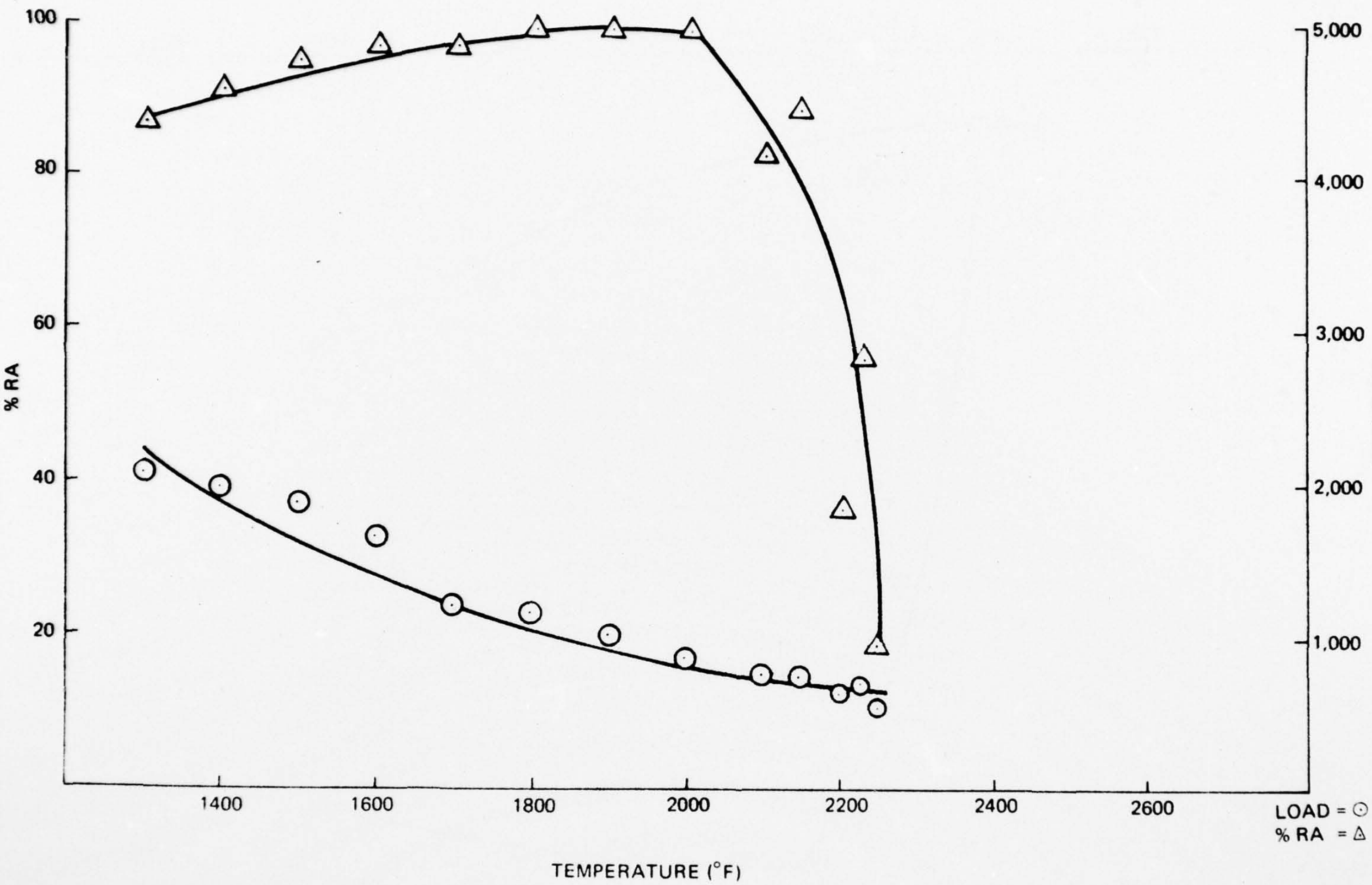


Figure 7 - AISI 1095

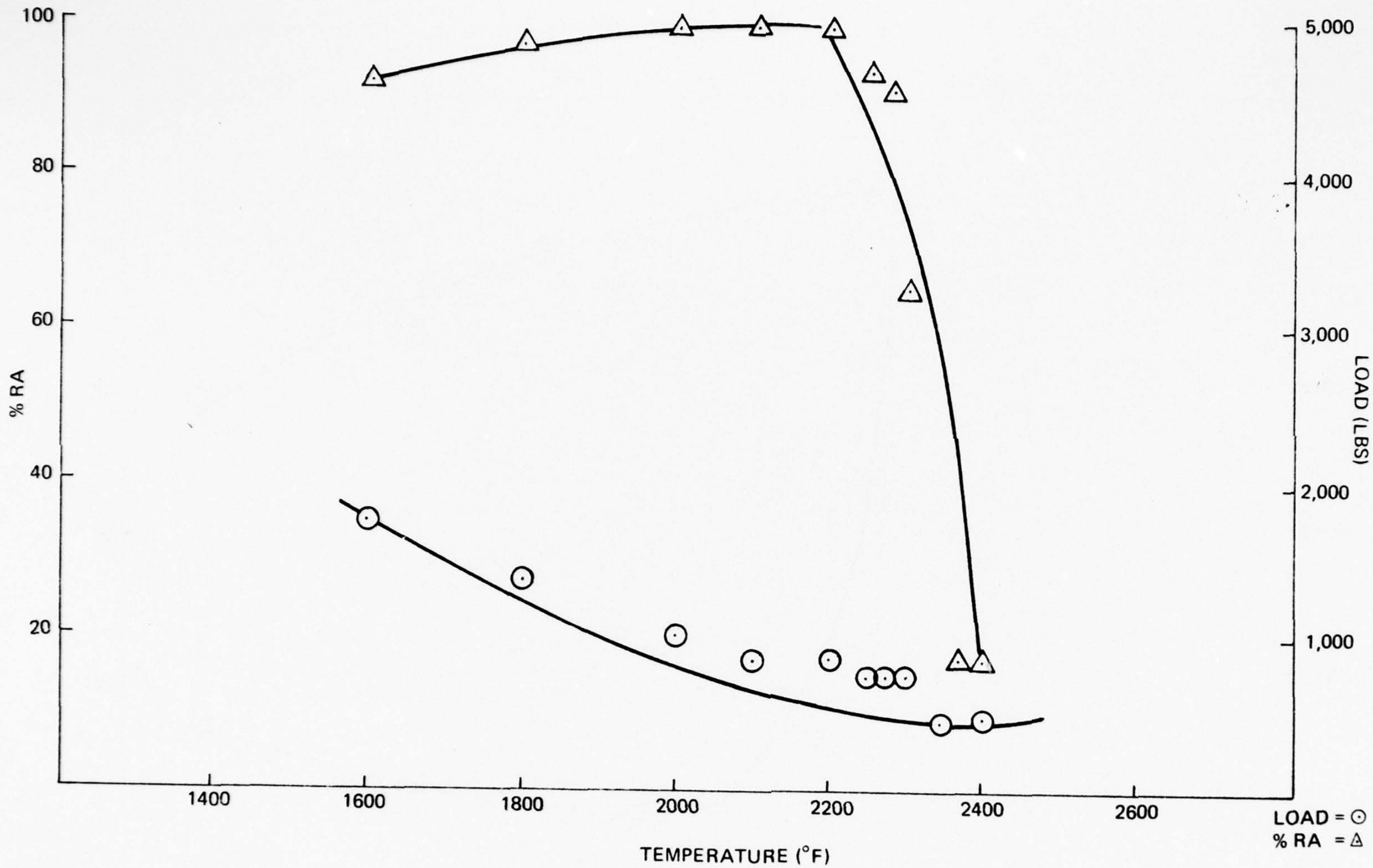


Figure 8 - PR-II

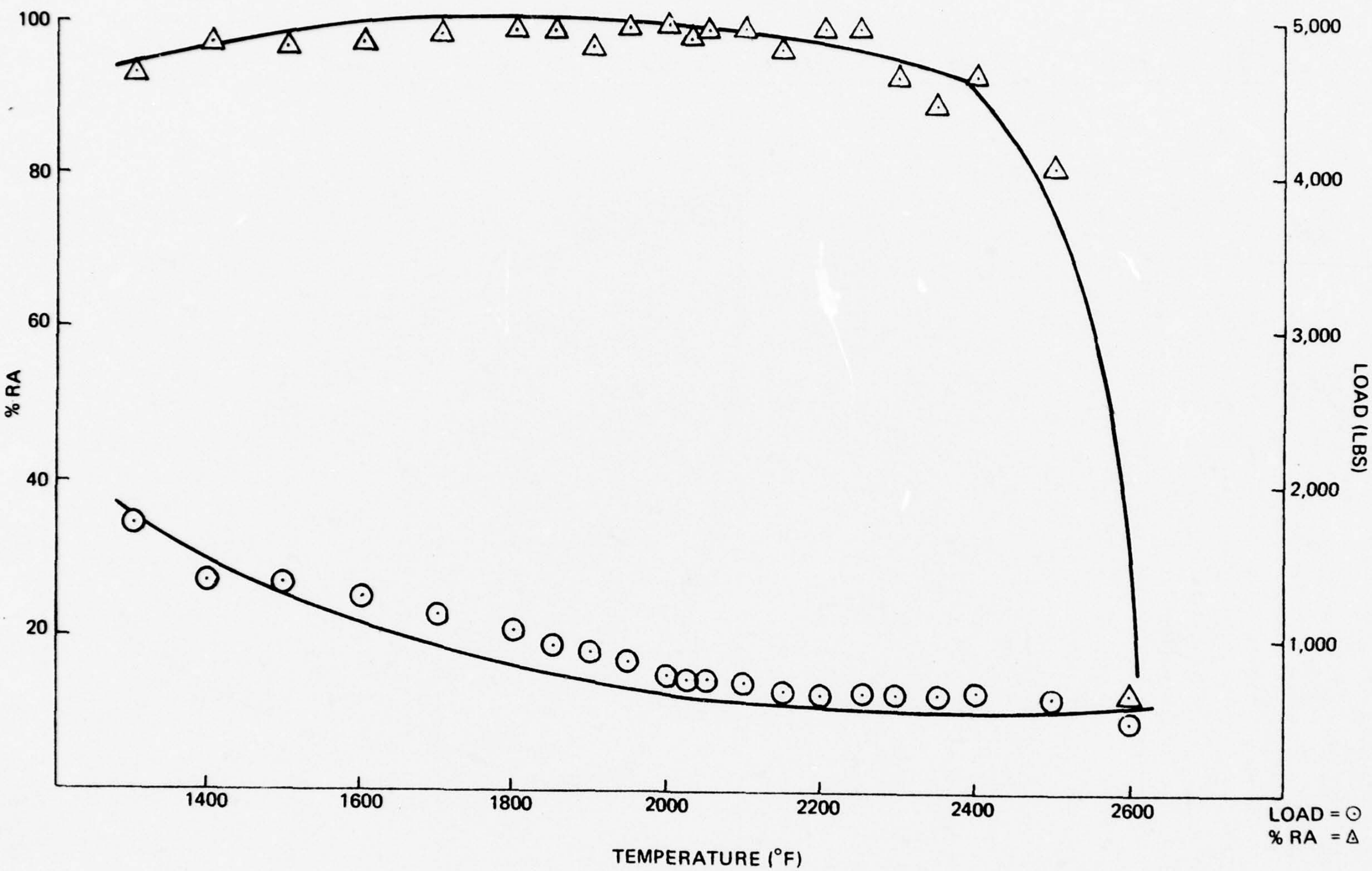


Figure 9 - AISI 1012

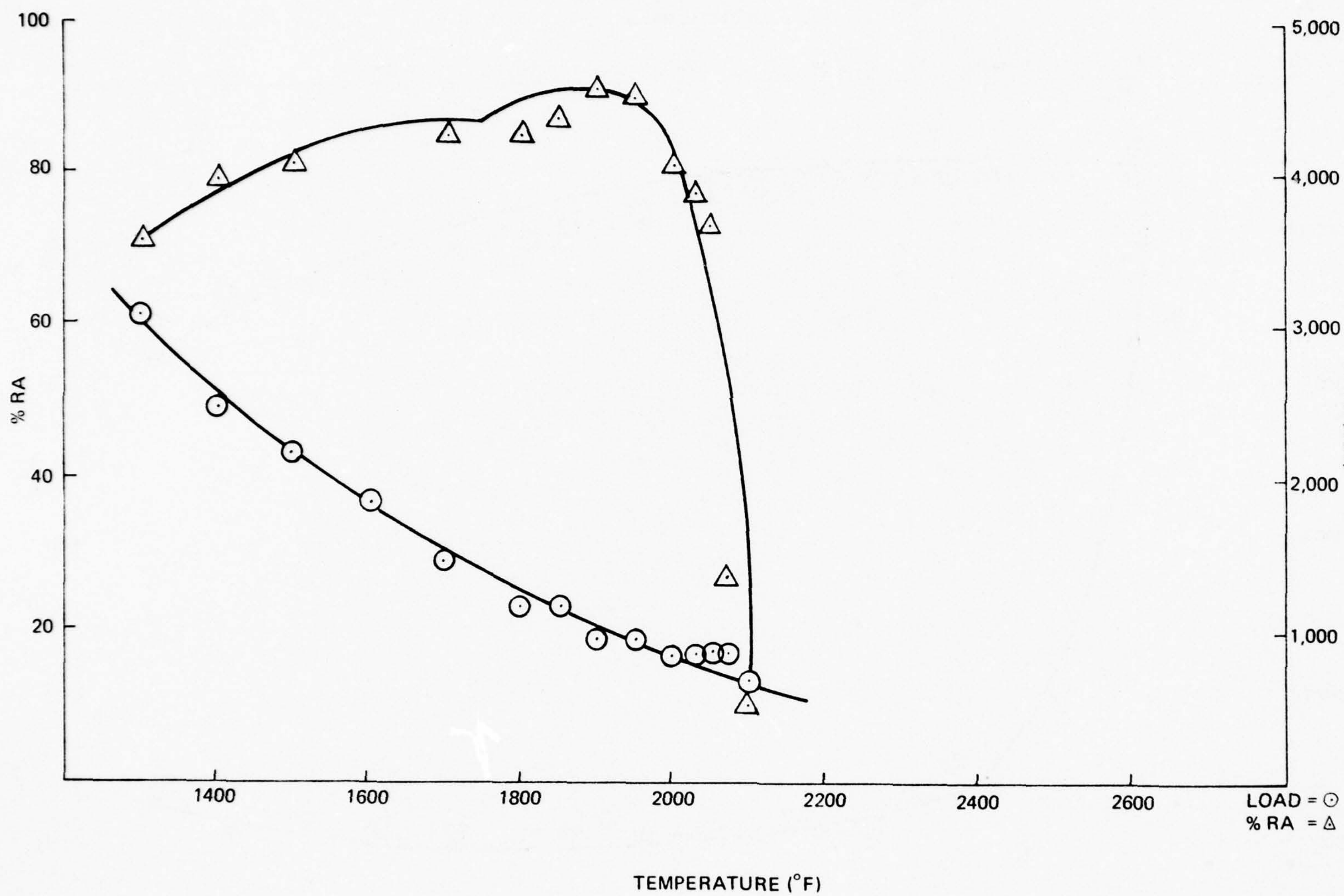


Figure 10 - AISI 06

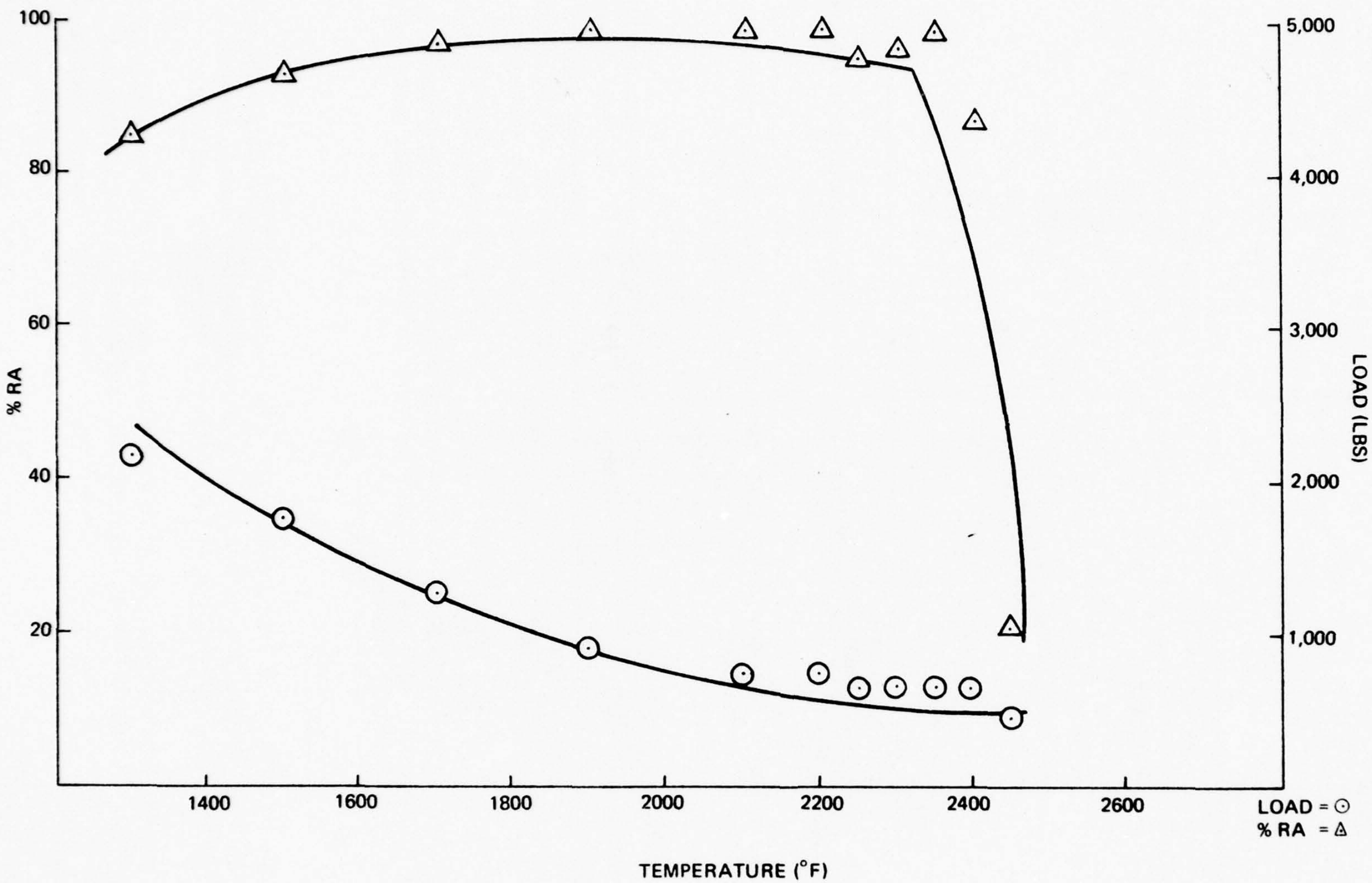


Figure 11 - AISI 1340

TABLE 9

MAXIMUM SAFE HEATING TEMPERATURE

MATERIAL	TEMPERATURE (°F)
AISI 52100	2000
HF-1	2050
AISI 1045	2000
AISI 1095	2000
PR-II	2100
AISI 1012	2250
AISI 06 Tool Steel	1900
AISI 1340	2100

(2) Increased forgibility should result in fewer rejects for metal separation or incomplete die fill.

(3) Decreased tonnages at the top of press working strokes should result. This would allow the option of using mechanical in lieu of hydraulic presses for some forming applications.

A direct benefit resulting from this study is the ability to estimate the percent increase or decrease in the tonnages required for forging similar shapes from the tested steels. As an example: Figure 6 and 8 reveal that the fracture strengths of the AISI 1045 and HF-1 specimens at 2000°F were approximately 700 and 900 pounds respectively. The approximate increase in load to forge a shape from HF-1 steel compared to AISI 1045 would then be: $\frac{900-700}{700}$ or 29%. This method of estimating the differences in tonnages required for forming should prove to be highly useful in the determination of required press characteristics for forming similar shaped projectiles from alternate materials.

7. Tool Design Study

Tool design practices of the plants visited by Frankford Arsenal Engineers were examined to determine if any modifications or changes could be made to decrease the cost of projectile manufacture through a reduction of the starting billet weight.

A review of the technical literature available at Frankford Arsenal coupled with engineering assessments indicated that significant cost savings could be realized through the use of contour tooling, reduced draw ring diameter, and base thickness control at the pierce operation.

Reference is made to the "Supplementary Report on Shell Forging" by the American Society of Mechanical Engineers dated 1 December 1945. The following is an excerpt from that report: "Forging with a contoured cavity saves 12 percent of steel in the 240MM shell, 9 1/2 percent of steel in the 8 Inch M106 shell and 5 1/2 percent in the 155MM Shell."

A typical billet weight for the 155MM Projectile is 118 pounds. Based on the above data, contour tooling would permit a reduction of approximately 6.5 pounds in the starting billet weight and result in a cost savings per projectile of approximately \$.81 based on a December 1975 steel price of \$.125 per pound.

Contour tooling is presently being used by one manufacturer in the production of the 155MM M107 with a significant reduction in billet weight realized. The probable reason that contour tooling is not utilized by other manufacturers is that the tooling is considered proprietary by the manufacturer utilizing it and because of the thinner forging wall produced by contour tooling. The thinner forging walls lose heat at a more rapid rate then conventional forging and means must be provided to rapidly transfer the forged part to the next operation. Furthermore, improved concentricity is required in the forge and draw operations to assure that the part will clean up in subsequent machining operations. The new presses currently being purchased and installed in manufacturing plants such as Louisiana AAP are capable of achieving the concentricities required for contour tooling.

The improved concentricities of the presses purchased for projectile manufacturing plants may also affect cost savings in the draw operation. Figure 12 is a graphic illustration of billet weight vs. the diameter of the draw ring use for drawing a 155MM projectile. This graph was derived from the Frankford Arsenal Phase I survey report of hot forge plants dated February 1956. An examination of the graph indicates that a billet weight decrease of approximately 8 pounds can be achieved for each 0.10 inch reduction of draw ring diameter. At current stell prices, this would represent a savings of approximately \$1.00 for each 0.10 inch reduction.

Additional savings may be obtained through tightened control of base thickness in the pierce operation. Current forging tolerance through the base of a 155MM projectile is as great as 1/2 inch. Through tighter control of the forge tooling it is anticipated that the tolerance can be reduced to 1/8 inch. This would result in an approximate savings of 2 pounds or \$.25 per projectile.

The results of this analysis indicate that reduced weight of billet is perhaps the most important element for consideration in decreasing the cost of projectile manufacture. Contour tooling, improved concentricity and controlled base thickness are important factors which significantly contribute to reductions in starting billet weight.

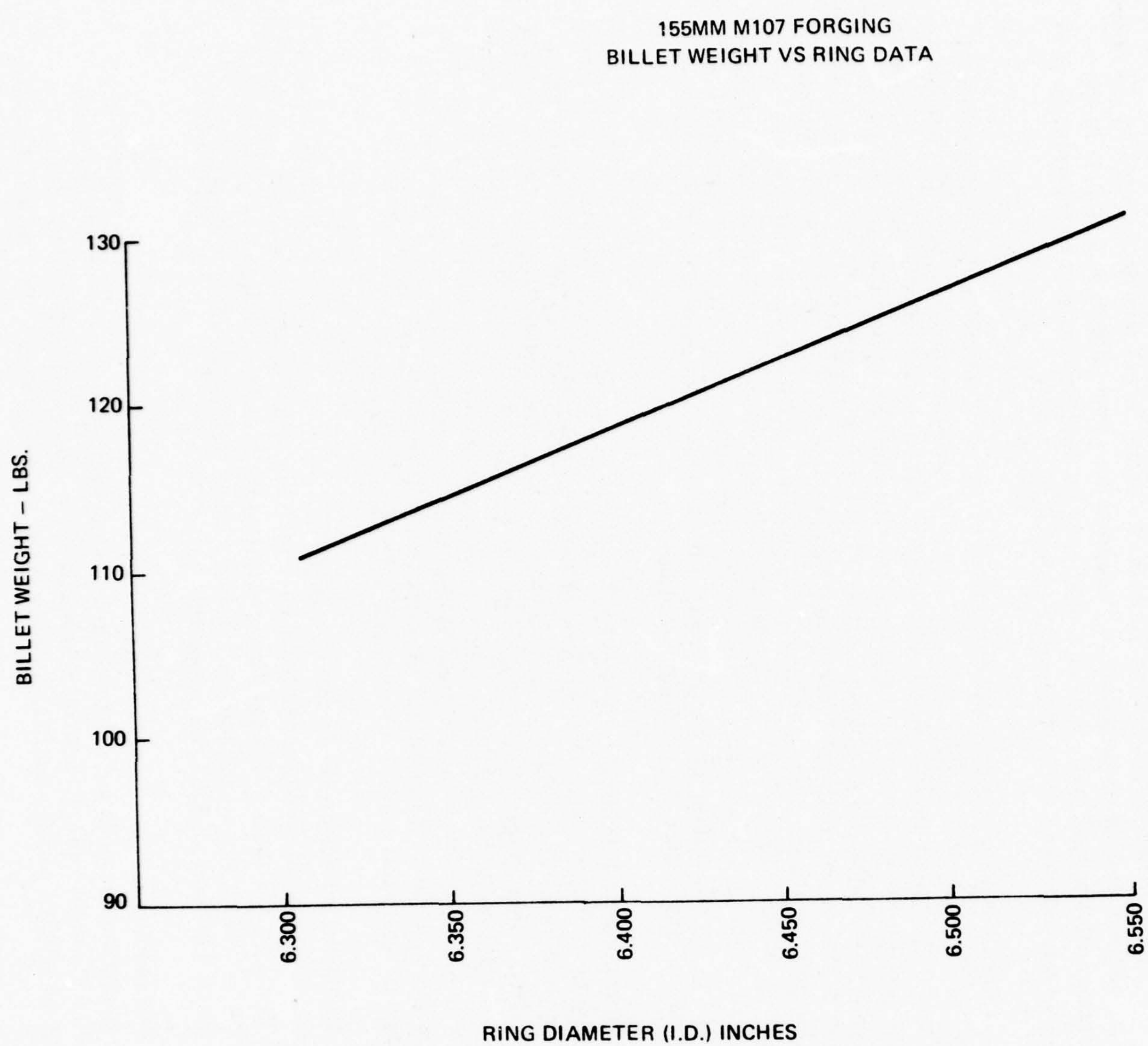


Figure 12 - Ring Diameter (I.D.) Inches

E. CONCLUSIONS

Forming is perhaps the area of manufacture which has the greatest potential for cost savings in projectile metal parts fabrication. Through the use of contour tooling, tightened draw rings and improved control of forming operations, less steel may be required for projectile manufacture.

The utilization of multiple linkage presses in lieu of hydraulic presses may result in higher production rates per press and reduced power requirements. This would lead to savings in capital equipment, floor space, manpower, and fuel costs.

Expanded usage of transfer presses incorporating a draw operation when feasible, should also result in reduced costs for equipment floor space, manpower, and energy.

Alternate forming processes such as squeeze casting and powder metal preforming may be applicable to projectile fabrication, and if implemented improved fragmentation and reduced material cost may result.

Savings may be obtained through the use of warm forming techniques. The elimination of the currently required spheroiding operation and its associated equipment coupled with a reduction of forging temperatures should result in lower equipment, energy and manpower costs plus a reduction in floor space. Furthermore, warm forming may permit the use of a non-polluting lubricant which would eliminate the need for costly pollution control equipment.

Mathematical modeling of forming operations could assure the optimization of equipment, tooling, and process for a particular forming operation and reduce lead time to production by eliminating the trial and error method currently used to a great extent in production setup.

F. RECOMMENDATIONS

In order to obtain the information necessary to evaluate and implement the above conclusions, it is recommended that the following studies be conducted:

1. Reduced Steel Requirements Through Modification of Forging Tooling

This study would attempt to reduce the starting weight of a projectile and, as a consequence, decrease its manufacturing cost. This would be accomplished through the design and implementation of contour tooling in production of the 155MM M107 at artillery metal parts plants. In addition to contour tooling, the feasibility and cost effects of reduced draw ring diameters and controlled base thickness of the forgings would also be examined.

2. Multiple Linkage Press Study

This study would be directed at a theoretical determination of the economic and technical feasibility of utilizing multiple linkage presses, such as the Bliss power bar, in lieu of hydraulic presses for all forming operations now limited to hydraulic presses because of long work stroke requirements. If successful, this project would provide the engineering data necessary to implement multiple linkage presses into artillery metal parts production.

3. Transfer Press Study

This study would determine the feasibility and cost effectiveness of utilizing transfer presses for artillery and mortar metal parts manufacture. Those artillery and mortar manufacturing plants utilizing single function presses would be visited and a determination made as to the feasibility of combining various forming operations, now performed on multiple presses, into a single transfer type press. In order to assist in the determination, the press manufacturing industry would be contacted for recommendations and suggestions.

4. Squeeze Casting Study

This study would evaluate the Squeeze Casting Process and obtain estimates relative to parameters of the process so that an economic comparison of Squeeze Casting vs. conventional methods of manufacture can be made. If the economic comparison proves favorable, additional efforts would be directed at conducting process studies toward finalizing the process parameters required to manufacture selected munitions components on a high volume production basis. The end product of this project would be specific knowledge concerning fabrication of munitions shapes by Squeeze Casting along with recommendations for implementation into production.

5. Warm Forming Study

This study would evaluate the feasibility of warm forming projectile metal parts in lieu of hot forging on a mass production basis. The objective of the study would be to reduce the cost of manufacturing artillery and mortar manufacture by: reducing the energy required to heat the mult, eliminating the spheroidizing operation required for machining HF-1, reducing eccentricities in forming, and increasing tool life. The characteristics of various lubricants would also be examined to determine if such benefits as reduced tonnages, increased formability and the reduction or elimination of pollution can be achieved. Upon completion of this study, the optimal warm forming temperature would be known and the resultant cost savings and process improvement available. The information derived from the study would be made available to all metal parts manufacturers for implementation.

6. Mathematical Models for Forming

This study would provide a predictive, computerized diagnostic tool for the design and optimization of each metal forming operation in the manufacture of projectile metal parts. Specifically, this study would address the following areas of projectile forming: lubrication, blocking, cabbaging and piercing, nosing, and shearing. The end result of this study would be a computerized model capable of predicting the following for both current and future projectile designs and materials:

a. Optimum forming temperatures

b. Ram speed effects

c. Load vs. stroke requirements

d. Buckling strengths

e. Optimum punch and die contours

f. Stress – strain rates

g. Permissible wall variations

h. Optimum rough turn configurations

i. Maximum permissible reductions in area

Among the benefits to be obtained from this study are:

a. Energy savings in forming

b. Improved tooling life

c. A rationale for predicting suitability of present equipment for future projectile

d. Elimination of a time consuming trial and error method of process and tool development

e. A rationale for predicting effects on present equipment to changes in rates, temperature, lubricants, product material, etc.

f. Development of a tool library of NC tapes which could be used by any plant for the manufacture of tooling and which could significantly reduce plant start-up time.

The end result of this study would be a computerized model capable of designating the optimum combination of process variables and tooling for forming projectile metal parts.

G. REMARKS

An investiation into the use of powder metal preforms for fragmenting type munitions is currently being conducted by Frankford Arsenal under Project No. 5746211. A small quantity of 60MM HE M49A3 projectiles has been successfully formed from cylindrical shaped preforms. Initial indications are that the process is competitive with the wrought process and fragmentation is similar. Attempts to fabricate the 60MM HE XM720 utilizing powder preforms are currently being undertaken.

SECTION THREE

METAL REMOVAL

A. INTRODUCTION

Machining is defined here as those metal removal operations required to convert the forging or extrusion into the final dimensional requirements.

B. PROJECTILE MANUFACTURING PRACTICE

Metal removal operations, in most of the plants visited, were similar in nature. In general, the use of disposable carbide inserts are used throughout the industry. However, at one plant, ceramic cutting tools are being used for the finishing operations.

Single point tooling is being used for turning, boring, facing and threading. Gang tooling is generally used in rough turn and finish turn operations to obtain higher production rates. Form tools are used to cut the band seat with dovetail, obturating grooves and turn the band itself.

With the exception of recent equipment purchased, it was observed that most of the machining equipment was purchased in the early fifties with some equipment of still an older vintage. Generally this equipment was manually loaded and unloaded and equipped with only adequate horsepower.

C. CRITIQUE

Observation of the cutting procedures themselves revealed that floor to floor time could be significantly reduced in several ways. It was observed, for instance, that in some cases where turning and facing is being accomplished, that first turning is performed, then a dwell time occurs, then facing is performed. Recent machine tools purchased perform these operations simultaneously where possible, thereby, reducing the quantity of equipment, cutting time, direct labor, etc. These findings have already been reflected in Frankford Arsenal specifications for machining equipment. As a result of the existing practice, Frankford Arsenal specifies the machining requirements attempting to combine operations, where possible, to reduce cutting time and floor to floor time. The Frankford Arsenal specifications also require higher horsepower, power trains, greater spindle speeds (capable of adopting to ceramic tools if developed) and higher torques at the spindles along with automatic load and unload features complete with two way automatic chip transport systems. Equipment has already been purchased to these specifications meeting all functional requirements. Higher speeds, combined metal cutting operations, automatic load and unload, automatic chip

transportation, all combined to reduce the number of pieces of machining equipment required in a line, floor space, direct labor, indirect labor, maintenance, etc. Further, the new machine tools will be able to produce similar size future projectile designs in an efficient manner which is not possible with today's equipment. For example, a comparison of the 155MM M107 machining line at Twin Cities AAP by the old process vs. the new process advocated by Frankford Arsenal under which the new equipment was purchased indicates that by combining operations and utilizing automatic load and unload features, 30 machines and 10 operators can replace 74 machines and 74 operators.

OLD PROCESS

OPERATION	NO. OF MACHINES	NO. OF OPERATING PERSONNEL
1. Center & Cutoff	9	9
2. Rough Turn & Base Face	16	16
3. Bore, Face & Chamfer	8	8
4. Finish Turn (Not Including Boattail)	14	14
5. Saw off Boss	4	4
6. Machine Boattail & Face Base	8	8
7. Thread	4	4
8. Machine Band Seat	6	6
9. Machine Band	5	5
	74	74

NEW PROCESS

OPERATION	NO. OF MACHINES	NO. OF OPERATING PERSONNEL
1. Center	2 (Dual Station)	1
2. Rough Turn, Face Base & Cutoff	11	3
3. Bore, Face & Chamfer	4	1
4. Finish Turn (Incl. Boattail)	7	2
5. Mill Base & Tap	2 (Dual Station)	1
6. Machine Band Seat	2	1
7. Machine Band	2	1
	30	10

Another observation made during the survey was that dimensional control within the process itself was poor. This situation led to added operations. For instance, several plants still use a final face base operation to bring the overall weight of the projectile into tolerance. By controlling base thickness from the start of the process,

this correcting operation is no longer required. This action not only eliminates a machining operation but also reduces the weight of the forging itself which has significant economic impact on the production unit cost.

It was also observed in another plant that the contractor was producing projectiles on three different machining lines because of three different types of equipment being utilized for the same machining operation. Although it was possible to successfully produce projectiles under this condition, added costs in forging weight and handling has resulted in a partly inefficient operation. Based on the experience of this producer, it is clear that for each step of the process such as rough turn, finish turn, etc., the equipment in that operation should be the same within the line and for each line.

In many cases it was observed that the equipment on hand at the producers plant, in esscence, dictated the machining process that was employed. There was usually only so much equipment available and this equipment had particular limitations. Once any equipment is purchased it must be purchased with a particular metal removal operation in mind. Some added flexibility can be obtained by purchasing more powerful equipment and equipment basic in design. Where possible, equipment purchased should attempt to use standard commercial products that have been adapted to our particular need. This type of equipment can, in many instances, be adapted to other needs in the future. Most machine tool builders attempt to build a basic machine tool that they can adapt to their customer's particular need. By taking advantage of this concept we also achieve the versatility inherent in these machines. Special equipment, tailor-made to a particular operation should be avoided, where possible, if we are to maintain the flexibility we desire in future production lines.

Discussion with machine tool builders and cutting tool producers reveals significant changes in metal removal are starting to occur. Such things as solid state controls and variable speed motion to maintain constant cutting speeds are starting to be introduced into production setups to reduce floor to floor time and direct labor costs. Further the costs of these improvements are continuing to decrease, allowing competition with fixed control systems.

Equipment with higher speed capabilities and more rigid frames is starting to bring about significant improvements in cutting tools. Where surface speeds for cutting operations were previously in the range of 300-350 SFPM they are now in the range of 400-450 SFPM for the same operation with speeds of 650-700 SFPM now being reported for some operations.

Ceramic cutting tool speeds, of course, are much higher but application has been limited to date. It appears, therefore, that cutting speeds will increase in an increment at a time rather than at one large step as we might obtain in moving from today's carbides to tomorrow's ceramics.

Since machining contributes to a large portion of the unit cost, it is essential to stay abreast of the state-of-the-art to realize any improvement that could result in reducing unit cost. With the purchase of new equipment, this becomes more important than ever. As better cutting tools become available, the new equipment should be able to take immediate advantage of this change or improvement.

A special type of form grinding, "Crushtrue" abrasive machining has recently been marketed by Bendix Corporation. The method uses wheel speeds up to 20,000 r.p.m. and a high pressure water jet to keep the wheel clean.

The Budd Company recommends possible alternatives for cutting tools to be used in ordnance manufacture. The following are the alternatives:

(1) Ceramics

(2) Coated Carbides

(3) High Speed Tool Steel

(4) UCON

(5) Close grain carbides

Machining not only involves metal removal but deals intimately with the philosophy of dimension. How you chuck a part, how you locate, how to machine and to what tolerance all play a part in the machining process. Each machining process prepares the part for the next machining operation. Dimensional control is the ultimate objective in machining. For example, by holding base thickness to a reasonable machining tolerance, excessive weight variation and the need for weight correction can be avoided.

Cutting fluid is an important factor in the efficient machining of metals. It acts as a coolant and lubricant, reducing friction, and temperature at the tool workpiece interface. This results in longer tool life, improved surface finishes and increased feeds and speeds, where possible.

D. STUDIES

Ceramic Tool Study

A study was undertaken to determine if ceramic tooling was feasible in the machining operations for manufacturing artillery shells.

This study was initiated as a result of the Budd Company's recommendations to investigate various cutting tools and the alleged use of ceramic tooling by Norris Industries on the profile turn operation for the 81MM HE M374 projectile. This allegation

was investigated; and it has been confirmed that ceramic tooling is being used by Norris.

The Budd study indicated that ceramic tooling was being used by the automotive industry for the boring of engine blocks and also for the finish turning of brake drums.

The study indicated the following advantages of ceramic tooling:

Lower Cost Thru:

1. Faster speeds
2. Longer tool life
3. Decreased cycle time
4. Increased production rate
5. Fewer machine tools required for an operation
6. Less floor space
7. Decreased equipment cost
8. No coolant required

However, two severe limiting factors on the use of ceramic tooling were found to be:

1. Limitations of our existing machine tools in power, speed and rigidity.

2. The inherent brittleness of the ceramic tool itself which does not permit interrupted cuts.

The National Science Foundation has funded several research groups to increase the transverse rupture strength of ceramic tooling. In the last two years, however, success has been very limited.

Because of these limitations in ceramic tooling, fine grain carbide cutting tools such as the Baxtron were examined. Threading of HF-1 steel, a critical cutting operation, now accomplished only by tool steels was successfully accomplished by the Baxtron at approximately 2 times the speed. The estimated cost per piece using the Baxtron is 25¢ and the estimated cost per piece using an M43 tool steel is 16¢. If the cost of the Baxtron can be reduced to $40.00 per head, the cost per piece will be the same as the M43, and since the speed of the Baxtron is almost double that of the M43, less machine tools will be required for the threading operation reflecting a savings in equipment cost. However, Dupont, the only licensee for Baxtron has dropped out of this line of business. Other carbide companies are now beginning to produce fine grain

carbide cutting tools. These tools offer approximately a 50% increase in cutting speed, with resultant increase in productivity from our new machine tools, if adaptable.

E. CONCLUSIONS

Investigation of the present methods of machining in the projectile metal parts plants visited, clearly indicate that significant improvements can be made. These improvements can be realized by:

1. Combining individual machining operations where possible.

2. Utilizing new cutting tools, if feasible.

3. Close process control throughout.

4. Purchasing standard commercial lathes of sufficient rigidity and horsepower to accommodate future design projectiles.

5. Utilizing an optimum cutting fluid to reduce friction, thereby increasing the feeds and speeds of the equipment.

The above improvements will reflect in reduced unit cost of an item by reducing the quantity of equipment needed, direct labor, cutting time, etc.

F. RECOMMENDATIONS

1. Alternate Methods of "Metal Removal"

A cost study of form grinding vs. machining shells is recommended. The metal removal rates, capital investment cost and tooling cost for grinding should be based on the "Crushtrue" process. One major disadvantage of form grinding is apparent at this time. There is no scrap value for the metal removed during the grinding operation(s). Using the 155MM as produced at LAAP as an example/ the unprocessed chips generated by the turning operations have a value of approximately $20/ton. Approximately 37 pounds of chips per projectile are produced during processing. This results in a chip pay back of approximately $.37/shell which would be lost if form grinding were utilized.

2. New Cutting Tools

Engineering studies are recommended in the area of new cutting tools. Feeds, speeds and depth of cut needed in a specified turning operation should be better defined and a study made as to applicability of the new cutting tools to machining as known in

artillery manufacture. Coated carbides, high speed tool steel, UCON, etc. along with a continuing study on ceramics should be investigated. Manufacturing data should be compiled on the type of tool, cutting speeds, feeds and type of material machined in artillery manufacture over the last few years to provide a background for comparing the effectivity of different cutting tools.

3. Part Methodization

A basic study on process control should be initiated. This study would first identify, thru modeling and experimental tests, the source of dimensional variations and dimensional control. Metal removal and equipment interface could be better defined and improved functional specifications for metal removal equipment should evolve.

4. Cutting Fluids

A study should be initiated to evaluate the cutting fluids available and their potential use in artillery manufacture. In addition, because of high volume production operations, recycling of cutting fluids should be also investigated from both an economic and pollution control standpoint.

SECTION FOUR

HEATING AND HEAT TREATMENT

A. INTRODUCTION

Heating referred to in this section concerns the heating of the mult for forging or the heating of a portion of the forging prior to nosing.

Heat Treatment referred to in this section concerns the conventional heat treatment of the forging, that is, austentize, quench and temper. Stress Relieving is a form of heat treating used to reduce internal residual stresses generally imparted in the workpiece after a cold working operation. It consists of heating a workpiece to a suitable temperature and holding for a proper length of time.

B. PROJECTILE MANUFACTURING PRACTICE

Mult heating is accomplished in most of the plants surveyed by large gas fired rotary hearth furnaces. One plant had used salt pot type furnaces for heating, but only on a temporary basis. The other method used for mult heating was induction heating. Induction heating has been successfully employed on small mults used for conversion into eighty-one millimeter mortars with a mult cross section as small as two and one half inches, and large mults used for eight inch projectiles with a mult cross section of seven and three eight inches.

Heating for nosing has been accomplished in gas fired furnaces of both in-line tunnel and rotary design. Induction heaters have also been used. In all systems, only the ogive portion of the part is heated.

Heat treatment in all cases is accomplished at present in either oil or gas fired air furnaces. The use of electric furnaces for heat treatment was not observed.

Various types of heat treatment air furnaces were observed. Some furnaces are of the walking beam type where the parts are laid on their side in tandum; other furnaces use baskets where the parts are transported through the furnace in a vertical position, and other plants employed rotary type furnaces where the part stands in the vertical position.

In all cases, the oil quench was accomplished with the part in a vertical position placed over a spud that quenched the cavity of the part while agitated oil surrounded the outside of the part.

Stress relieving for those plants employing the hot cup-cold draw process was accomplished in gas fired furnaces while one plant stress relieved in an electrically heated salt pot.

Observation of those plants using gas or oil fired heating furnaces revealed considerable scale buildup unless atmosphere control was being used as compared to the induction heater which produced relatively little scale. The time for heating "mults" in the gas or oil fired furnaces was considerably longer than that for induction heating. The survey revealed however, the most pressing problem in billet heating at present is the availability of an energy source. In most instances, furnaces can be purchased that will operate efficiently in either gas or oil. In one case, a furnace manufacturer is involved in furnace design that can use gas, oil or electricity. Most plants surveyed that use gas for mult heating are under severe restrictions and cannot expect gas to be available during certain high demand periods — the winter months — since they have a lower priority than residential heating. As a result of this situation, many of these plants converted, or are converting, to a dual capability of operating on gas or oil. This necessitates the construction of a storage site for oil, which in some cases, has already been accomplished. Oil itself, offers special problems in regard to pollution, and therefore, low sulfur oil must be used. The continued availability of this oil and the future cost picture of low sulphur oil looks uncertain at present and more pressure is mounting to convert to electric heating. Those plants already using electric induction heating appear optimistic as to future availability of electricity; however, if all of industry begins to convert to electric heating, the increased demand can be expected to cause problems.

A similar situation exists for furnaces used for heat treatment. Gas fired furnaces are used for stress relieving in those plants where the hot cup-cold draw process is used except for one plant that stress relieves in an electrically heated salt pot.

C. CRITIQUE

Clearly, the most immediate problem to be confronted in the area of heating and heat treatment has to do with taking the proper steps to assure a continuous operation in the future. The use of alternate energy sources for heating and heat treatment is apparent as a desirable move to make. However, steps can be taken to alleviate the present condition. The thermal efficiency defined here as the heat required to bring a mult up to forging temperature divided by the heat input into the system can be significantly improved. Literature revealed that gas or oil fired rotary hearth furnaces can have an operating efficiency as low as fifteen percent. Induction heaters are presently operating in the range of fifty percent thermal efficiency. A table of these results are tabulated in a later portion of this section. Discussion with furnace equipment manufacturers reveal that no real attempt has been made in the plant to control thermal efficiency since gas and oil were inexpensive. This does not mean that something can not be done at present. As a matter of fact, considerable effort is now being made to

improve thermal efficiency and design changes can be expected in furnaces in the not too distant future.

Induction heating for mults and for nosing is also being investigated and, in fact, due to the particular advantages of induction heating for nosing, specifications have already been written indicating this is the preferred method of heating for nosing. The use of induction heating for billet and for heat treatment are discussed later in this section.

The application of lubricant to the ogive, particularly the long, thin ogives, has been reported as critical by some of the projectile manufacturers. They suggest, and it is apparent, that the projectile should be preheated and lubricant sprayed on with an evaporative carrier, thus drying before or in the main heating coils. This procedure, it was observed, results in an almost painted surface finish for the lubricant and nosing proceeds smoothly and easily. This procedure has been used to some extent at Frankford with good success and the concept is already being procured for one of the operating contractors plants and is presently being incorporated into existing equipment specifications prepared by Frankford Arsenal. The idea is not new since it has been accomplished piecemeal in at least one of the successful operating contractors, but it is the first time a <u>system</u> approach to optimize nosing is being made for heating equipment.

The use of alternative quenchants in place of oil are also being studied. Oil presents problems associated with fire hazards and pollution abatement. Alternative quenchants are aimed at alleviating or eliminating these problems.

As discussed in the section on billet separation, certain billet separation techniques often result in irregularly parted surfaces with loose, partially severed metal which in subsequent forging operations, causes critical defects in the projectile cavity. Scaling of the parted surface during heating for forging is another cause of cavity defects. In the induction heat-hot shear system, the whole billet is heated to forging temperature. The billet is fed an increment at a time to a hot shear press which separates the mult from the billet. The hot parted mult has a new clean surface immediately prior to forging which tends to eliminate scale. Further, the transport of a billet thru a series of induction coils is considerably less troublesome then pushing separate mults thru a similar system. In addition, the thermal efficiency is slightly higher for heating a long billet as opposed to heating a series or column of mults.

As discussed previously, several techniques exist for heating the nose of the projectile. However, discussion with the various operating contractors indicate significant advantages exist in the induction heating techniques when approached as a system. It can be anticipated that based on review of future designs that ogives will continue to be greater in length and thinner in cross section. An examination of the buckling formula presented in the forming portion of this report clearly indicates these long

thin ogives will be more difficult to form while avoiding upsetting. In fact, it appears that two nosing operations may be required where only one operation is required for our more conventional projectile designs. Since induction heating is much faster than heating by gas or oil, the heat transfer to the adjacent areas is much less. This means the real strength of these areas is higher than the strength of the area to be nosed thus reducing or perhaps eliminating the projected problem of buckling. This, in turn, may permit long, thin ogives to at least be more successfully nosed in one operation, thus maintaining our productivity of our existing nosing presses.

It appears that in the event a particular ogive design indicates the nosing cannot be accomplished in one operation, the division of these forming operations into two steps without reheating and on one press may still be possible thus maintaining the productivity of our existing press system.

D. STUDIES

1. Induction Heat Treatment

Frankford Arsenal initiated feasibility studies in induction heat treating of standard HE-type projectiles and ICM-type projectile bodies. The study to investigate the feasibility of induction heat treating standard HE-type projectile bodies was initiated as a subproject under MM&TE Project #5736550, and was conducted at TOCCO Industries, Cleveland, Ohio. The study to investigate the feasibility of induction heat treating ICM-type projectile bodies was initiated under MM&TE Project #5736580 and was conducted at AJAX Magnethermic Corp., Cleveland, Ohio.

Under the 6550 program, the basic work effort was the design and fabrication of a single shot, static-type induction coil with related fixturing to be adaptable for use on TOCCO's existing 300 KW, 3000 Hertz Laboratory power supply and to develop the optimum operation parameters to heat treat semi-machined in-process-type 155MM M107 projectile bodies to meet the minimum mechanical property requirements of 165,000 psi minimum yield strength with a 15% minimum elongation.

The 155MM M107 projectile body has a nosed-type forward body shape with an aft boattail closed-base configuration. Under this program, TOCCO utilized a "single shot" method of heating the M107 projectile body to both the austenitizing (1600°F) and tempering (1200°F) temperatures. In this method the entire projectile was encased by an encircling multi-turn, multi-diameter coil-type inductor, positioned vertically with the nose end (open end) of the projectile body in the "down" position. The coil was designed with variations in gap spacing between the turns and with variations in turn diameters to compensate for the variation of space between the coil and the projectile profile.

In the heat treat operation, the M107 projectile body was manually loaded and positioned onto the fixturing of the machine. The nose portion of the projectile body rested on a circular "doughnut-type" location ring and the boss which extended from the base was used to support the base-end of the projectile body. The mechanism on the machine automatically positioned the projectile body within the coil for austenitizing. The entire projectile body was heated in a "single shot" to the austenitizing temperature. After the austenitizing temperature of 1600°F was obtained, the projectile body was lowered into a quench tank and submerged over a spud and quenches both internally and externally by an agitated synthetic quench bath. After quenching, the projectile body was raised from the quench tank and returned to the original position within the encircling coil-type induction for a "single shot" temper at 1200°F. The projectile body was manually unloaded from the induction unit.

Thirty-two projectile bodies were provided to TOCCO for this study. Twelve were earmarked for development of the heat treat process parameters and the balance of the twenty for heat treatment evaluation. Initial test results indicated difficulty in obtaining an acceptable temperature profile. The temperature distribution was too non-uniform, the center portion of the projectile body being the hottest with both ends substantially cooler. Respacing the coil turns improved the temperature profile of the nose end, but the base end still remained substantially cool. To improve the temperature profile primarily in the base end of the projectile body, TOCCO decreased the diameter of the coil turns to increase the inductance, three capacitor contacts were added to the circuit to increase the power level, and a two turn pancake-type coil attachment was placed over the base of the projectile body at the top open end of the coil to help induce heat into the base area of the workpiece. The doughnut-shaped stainless steel locator ring which had a tendency to overheat was also changed to a water cooled income tube arrangement.

Additional test results indicated that difficulty was still obtained in getting sufficient heat into the base area of the projectile body. TOCCO replaced the two turn pancake coil attachment with a Ferrocon ring flux concentrator to help induce flux into the base portion of the workpiece.

TOCCO also experimented with the synthetic quench media. Concentrations of UCON (synthetic quench) varied from 6% to 25%. Austenitized projectile bodies quenched in the lower concentration range produced non-uniform hardness readings varying from Rc38 to Rc57 at the surface of the wall to Rc19 in the base area. A 25% UCON which simulated a quenching speed closer to that of oil was eventually utilized.

The following operating parameters were established by TOCCO utilizing the best effort obtainable from their 300 KW, 3000 Hertz powered laboratory machine to achieve the end item heat treat requirements. One coil was employed for both austenitizing and tempering operations.

Final Austenitizing Cycle: The 4 minute austenitizing cycle established to heat the projectile body under continuous power to 1600°F was the following:

Power KW	% Power of 300 KW	Heating Time (Sec)
300	100	0 to 80
150	50	80 to 95
120	40	95 to 135
90	30	135 to 150
60	20	150 to 240
		Power OFF at 240 Sec

Final Quenching Cycle: The quench media was composed of 25% of UCON which simulated a quench rate equal to oil. The quench bath temperature was maintained between 90 to 120°F. The projectile body was submerged in an agitated quench media and subjected to both an internal (spud) and external quench. The quench cycle of 9 minutes was the following:

Quench Time – 8 Min

*Delay Time – 1 Min

*Delay time included the total index time from austenitize to quench and from quench to temper.

Final Temper Cycle: The 6 minute tempering cycle established to temper the projectile body at 1200°F utilizing pulsed-type power was the following:

Temper Time Utilizing 156 KW of Power

Power Cycle ON (sec)	Power ON (sec)	Power Cycle OFF (sec)	Power OFF (sec)
0-20	20	20-60	40
60-72	12	72-100	28
100-120	20	120-220	100
220-250	30	250-350	100
350-358	8	358	OFF

Total Heat Treat Cycle Time per Projectile Body

Austenitize	4 Min
Quench & Delay	9 Min
Temper	6 Min
Load & Unload	1 Min
Total Cycle Time	20 Min

The heat treated projectile bodies were evaluated at Frankford Arsenal for mechanical properties, hardness pattern, microstructure, decarburization and heat treat cracks. The following data was obtained from projectile bodies heat treat by TOCCO under the aforementioned final operating parameters.

Mechanical Properties Test

The following mechanical properties were obtained from three projectile bodies. Two longitudinal tensile test specimens 0° and 180° apart were removed from the areas of the projectile nose, the band seat, the boat tail and one transverse tensile test specimen was removed from the area of the base. The mechanical properties requirements throughout all areas of the projectile body are 65,000 psi minimum yield strength at .1% offset with a 15% minimum elongation. The mechanical properties were compared to those obtained from a projectile heat treat by the conventional heat treat method.

Problems were encountered in being able to meet the minimum mechanical property requirements in the base area of the induction heat treated projectile bodies. The hardness pattern through the center of the base cross-section of these projectile bodies ranged from Rockwell "C" 8 to 12 as compared to a Rockwell "C" 16 for the conventional heat treated projectile body. Microstructure analysis of the induction heat treated projectile bodies indicated that little through heating of the material in the area of the base was obtained during the austenitizing and tempering cycle.

Decarburization was within .005 of an inch on the metallurgical sections examined. The projectile bodies were magnetic particle inspected and found to be free of heat treat cracks.

Acceptable induction heat treated projectile bodies were not obtained under this study, however, the study did demonstrate that the actual heat treat cycle time is longer than originally estimated making induction heat treating no longer economically cost effective with conventional heat treat methods. It is recommended that conventional heat treat systems be used to heat treat HE-type projectile bodies. If a technology base need exists to prove technical feasibility of induction heat treating the 155MM M107 projectile body for a time when gas and oil are not available, it is recommended that a competitive contract be placed to design and fabricate a prototype production machine that can be set-up and evaluated under a production operating condition. It is also recommended that a 1000 hertz or less power supply frequency be used to achieve greater heat penetration in the base area for the workpiece and that two in-line induction coils (one for austenitizing and one for tempering) be utilized for better heating control and that the coils be positioned horizontally to provide a more expedient indexing approach for a production operation.

The results of the feasibility study on induction heat treating ICM-type projectile bodies under Project #5736580 will be covered under a separate report.

MECHANICAL PROPERTY TEST

Projectile	Tensile Strength (psi) 0	Tensile Strength (psi) 180	Yield Strength (psi) 0	Yield Strength (psi) 180	Elong % 0	Elong % 180	Red Area % 0	Red Area % 180
Ind H. T. Proj #1								
Nose	118,300	117,800	80,100	77,600	20	19	56	54
Bandseat	126,900	123,100	78,700	77,700	16	18	44	46
Boattail	126,700	113,100	78,900	77,800	18	18	40	54
Base	96,500		49,000*		12*		17	
Ind H. T. Proj #2								
Nose	121,000	119,200	81,500	80,700	21	20	56	55
Bandseat	122,600	125,500	74,500	80,100	14*	14*	34	34
Boattain	123,200	131,700	74,400	86,200	15	16	37	40
Base	96,500		49,100*		12*		18	
Ind H. T. Proj #3								
Nose	130,500	130,700	86,200	85,600	19	19	57	57
Bandseat	124,300	134,300	77,500	91,200	13*	14*	33	36
Boattail	122,000	126,200	78,100	77,500	15	15	49	35
Base	105,100		54,200*		13*		27	
Conventional H. T.								
Nose	122,100	123,000	88,200	87,900	24	22	61	60
Bandseat	121,500	122,800	79,300	79,100	20	19	51	49
Boattail	117,800	118,200	74,100	74,200	20	20	51	52
Base	112,800		69,500		19		44	

*Do not comply with minimum requirements

2. Alternate Quenchants

A study was conducted by Frankford Arsenal under MM&T Project Number 5731114 to determine if quenchants other than the currently used oil mediums could be used in the heat treatment of large caliber Projectile Metal Parts. The objective of the study was to eliminate the smoke, flame and fire hazards associated with oil quenchants.

A test was conducted at Chamberlain Corporation's New Bedford Division and Scranton AAP using the 155MM HE M107 as a vehicle. A total of 6,000 metal parts were heat treated using Houghton 251 Aqua Quench as the quench medium.

The results of the test indicate that the use of Houghton 251 Aqua Quench in concentrations of 18 to 20% and quench bath temperatures of 100-165°F, is feasible for heat treatment of the 155MM M107 projectile and reduced smoke, flame and fire hazards can be achieved. However, strict control procedures to maintain solution concentration and temperature within the specified limits are essential for successful application of aqua quench in heat treatment of projectiles on a production basis.

Recommendations contained in the study state that Aqua Quench heat treatment of 155MM M107 projectiles should be implemented on a trial production basis for a period of four months to firmly establish the process on a production basis prior to full implementation.

E. CONCLUSIONS

Examination of the present methods of heating and heat treating in the projectile MPTS plants visited, clearly indicates that significant improvements can be made. The use of induction type heating and heat treatment has many anticipated advantages as mentioned in this section of the report. Furthermore, in light of the gas and oil curtailments being anticipated, induction heating is a viable solution.

F. RECOMMENDATIONS

Further studies should be continued to verify under production conditions, the findings the initial studies surfaced. The systems to be further investigated are:

1. Induction Heat/Hot Shear Prior to Forging
2. Induction Heat Treatment
3. Aqua Quench for Heat Treatment

APPROXIMATE THERMAL EFFICIENCY OF VARIOUS HEATING METHODS

HEATING METHOD	THERMAL EFFICIENCY PER CENT
OIL-FIRED FURNACE	15 - 30
OIL-FIRED FURANCE (RECUPERATIVE)	20 - 40
GAS-FIRED FURANCE	15 - 30
GAS-FIRED FURNACE (RECUPERATIVE)	20 - 40
INDUCTION-HEATING UNIT BILLET	45 - 50
INDUCTION-HEATING NOSE	60 - 70

SECTION FIVE

MATERIAL HANDLING

A. INTRODUCTION

Material Handling in this report considers those transport systems required to move material from one operation to the next operation including the transfer stations at the interface points and all other transfers that may be required. An example would be the movement of a projectile forging from a Center and Cutoff Operation to a Rough Turn Operation. The material handling system would include the equipment required to remove the forging from the exit conveyor of the Center and Cutoff machine, place the forging on a transport conveyor to the Rough Turn Operation and transfer the forging to the automatic loading or feed conveyor that is an integral part of the Rough Turn Machine.

Chip transport systems are also included under material handling and provide for removal of the chips generated at a particular turning operation to a processing area for the chips and finally moving the processed chips to a rail car or other means of transport.

Material handling also includes the material handling system within a particular piece of equipment such as a lathe or furnace.

B. PROJECTILE MANUFACTURING PRACTICE

Of the several plants visited during the plant survey, various degrees of material handling were noted.

A plant using the Hot Cup-Cold Draw Process in the manufacture of the 81MM Mortar Projectile used overhead conveyors which were manually loaded and unloaded. All press and machine operations were manually loaded and unloaded. Tote boxes were used at several stations and were moved by forklift trucks.

Another plant using the Hot Cup-Cold Draw process in the manufacture of the 105MM M1 projectile used overhead conveyors that were manually loaded and unloaded with some transfer operations particularly at elevation being automatic. All press operations were fully automatic load and unload. A large amount of manual transfer was required for the machining operations due to a lack of automatic transfer equipment even though the machining equipment itself operated in an automatic or semi-automatic mode.

Another plant producing the 105MM M1 projectile by the Hot Forge-Heat Treatment Process was observed. Of the existing transfers between machines and conveyor or from conveyor to conveyor, approximately half were mechanized while the remainder were performed manually. Overhead conveyors were usually loaded and unloaded manually although loading of the overhead conveyor was accomplished automatically at the exit end of the heat treatment furnaces. All press equipment was loaded, operated and unloaded manually. The knurling, welding, threading, banding, grinding and stamping operations were automatically transferred to the respective machine tool equipment, through it and away from the machine tools.

The 155MM M107 projectile was observed in three different plants which used the Hot Forge-Heat Treatment process as the basic process of manufacture.

In one plant the forge line was being replaced during the survey with automatic load and unload presses which are capable of transferring the forging to the next press operation. This plant uses three hydraulic presses for Cabbage, Pierce and Draw and will operate in a completely automatic mode. The rest of the equipment in the plant is manually loaded and unloaded and manually operated. Transport is by floor mounted roller conveyors with very little power conveyor usage. Most projectiles were removed by pushing the projectiles on conveyors.

Another 155MM M107 producer using the Hot Forge-Heat Treatment process is also in the midst of modernization. Automatic press systems are being purchased that automatically load the billet into a mechanical Cabbage & Pierce Press and then transfers the forging automatically to a Hydraulic Draw Press. This system appears to work well and resulted in a significant reduction in direct operating labor in the forge shop. Overhead conveyors that are manually loaded and unloaded are used in this plant along with manually powered floor mounted roller conveyors. As a part of the modernization program in this plant, machining lines are being purchased with an integrated material handling system that provides the correct flow rate to and from each machine.

Another producer of the 155MM M107 using the Hot Forge-Heat Treatment process is operating a line assembled prior to 1950. All press and machine operations are manually loaded and unloaded. Floor mounted power roller conveyor systems are used to a great extent in this plant. This particular plant has worked with Frankford Arsenal in the procurement of automatic machine tools for both the Twin Cities Army Ammunition Plant and St. Louis Army Ammunition Plant. This equipment is being stored on-site at these two plants pending notice of disposition. The modern equipment purchased is fully automatic in the sense it can take a part from a conveyor, machine the part and return it to another conveyor. Material handling systems tying the equipment together has not yet been procured.

One plant that produced the 175MM M437 using the Hot Forge-Heat Treatment process was also surveyed. This plant was built in the late 1960's and represents a

modernized concept of that time. All presses and machine tool operations are fully automatic with automatic load, unload and transfer capabilities. The material handling system is integrated with the production and inspection equipment. During production, however, problems were encountered with this system due to the complexity of design of the system and represents the need for considerable planning prior to designing and installing <u>any</u> automatic system.

Another plant visited used the Hot Cup-Cold Draw process for manufacture of the 8 Inch M106 Projectile. The forge and machine lines are fully automated with automatic load and unload capabilities. The design of this line based on performance is considered highly successful and represents in our survey the most successful use of automation to date. This plant was constructed in 1952.

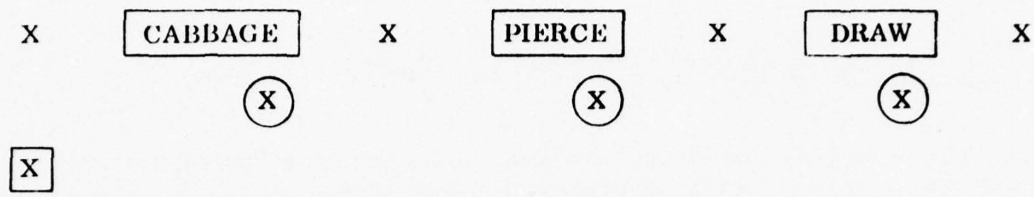
The manufacturing process and the material transfer between operations at the nine plants visited are shown in tables one through nine which appear at the end of this section.

Chip transport systems in most of the above plants consisted primarily of tote boxes adjacent to the machine tools. Centralized chip transport systems had been tried in the past but were unsuccessful in operation because of jamming and excessive wear. The net result of these experiences led to simply placing the chip tote boxes adjacent to the machine tool and then moving the tote boxes by fork lift truck to a central chip disposal area. Chips are not crushed or dried in any of the plants surveyed. Chips in this condition have a lower market value then crushed and dried chips.

C. CRITIQUE

The most significant finding in the survey was that even though modernization is going on in some plants, many plants are not giving sufficient thought to material handling whether it be the projectile metal parts or the chip transport system or some particular transfer station. It was observed that several of the plants now involved in final purchasing of equipment are beginning to realize the significance of the material flow thru the plant and, in particular, from operation to operation. Installation and testing of automatic machine tools and presses points out the need for automatic material handling systems and the benefits to be derived are becoming more obvious.

In one plant producing the 155MM M107 the advantage of an integrated automatic forge press line illustrates the point. Previously this line required three presses with operations as shown below.

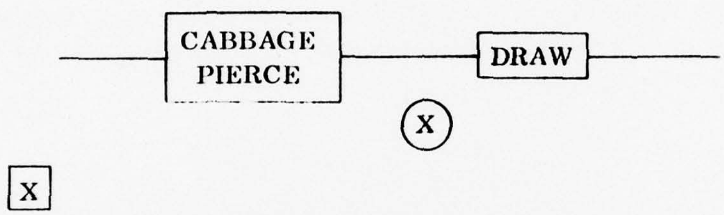


X Transfer Man – Load & Unload

X Press Operator

X Relief Man

The system now requires:



X Operator

X Relief Man Part Time

In the old system four transfer men, three operators and one relief man were required to operate the presses. This line produced 125 units per hour requiring eight men full time not counting tool setup men, etc. The new system requires one man plus a relief man as required, approximately half-time. This line produces 180 units per hour requiring 1 1/2 men not counting tool setup men, etc. Thus in comparison we have:

<u>Old System</u>

$$\frac{8 \text{ Man hours/hr}}{125 \text{ units/hr}} = 0.0640 \frac{\text{man hours}}{\text{unit}}$$

<u>New System</u>

$$\frac{1.5 \text{ Man hours/hr}}{180 \text{ Units}} = 0.00833 \frac{\text{man hours}}{\text{unit}}$$

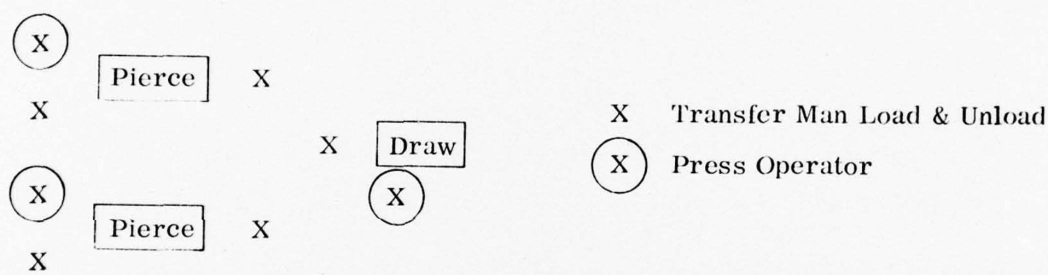
At an estimated cost of $12 man hour we have:

<u>Old System</u>: $0.0640 \frac{\text{man hours}}{\text{unit}} \text{ X } \$12 \text{ man hour} = \$0.768$

New System: $0.00833 \frac{\text{man hours}}{\text{unit}} \times \$12 \text{ man hour} = \$0.0999$

Here we see that the direct labor cost with overhead estimated to total $12/hour would cost $.77/unit for the old system versus $.10/unit for the new system. If one chooses to debate the validity of a total cost of $12/hour, the reduction in direct labor is shown as 0.0640 man hour/unit by the old system as compared to 0.00833 man hours/unit or a ratio of 7.68 and a reduction of 0.0566 man power required for the new system versus the old system. A similar reduction was projected for press equipment required to forge the 105MM M1 projectile planned for replacement at SLAAP.

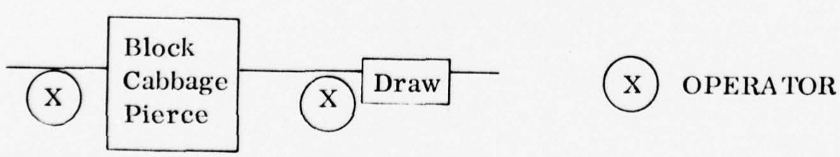
SLAAP used 20 Pierce Forge Presses and 10 Draw Benches for their forging operation. These presses were arranged as follows requiring the personnel as indicated.



SYSTEM A

Ten of the above setups were required to produce 800,000 units per month. Eight personnel were required per system for a total of eighty not counting tool setup men or relief men.

Under modernization with an integrated setup, five forge presses and five draw benches would be required with personnel as shown:



SYSTEM B

Five of these systems would produce 1,000,000 per month (500 hour month).

However, based on the use of load displacement curves it became apparent that the draw operation might be possible on a Mechanical press representing a reduction in overall investment cost and direct labor. One press company bid this way and the following system was purchased:

SYSTEM C

Here one needs: One operator for each of the five presses producing one million per month (500 hour month). The manpower per unit is shown below.

SYSTEM A

$$\frac{\text{800,000 Units/Month}}{\text{(500 Hrs/Month) (Eighty Men)}} = \text{20 Units/manhour}$$

SYSTEM B

$$\frac{\text{1,000,000 Units/Month}}{\text{(500 Hrs/Month) (Ten Men)}} = \text{200 Units/manhour}$$

SYSTEM C

$$\frac{\text{1,000,000 Units/Month}}{\text{(500 Hrs/Month) (Five Men)}} = \text{400 Units/manhour}$$

Here we see that the units per manhour for System C is twenty times greater then for System A. This advantage is due to the increased production rate of the press itself and the elimination of direct labor in transferring the part manually.

Similar situations exist for machine tools. In most of our older facilities we have one operator per machine tool. Under modernization with automatic equipment one operator should be above to monitor at least two production machines and based on trials of equipment purchased to date, one operator should be able to monitor four machines. This requires, by the way, the implementation of automatic inspection which by itself replaces the old manual inspection for process and final inspection resulting in significant reductions in manpower requirements.

It has been argued by some that automatic equipment costs more and therefore is not justified for modernization. If, however, we look at the payback ratio by reducing personnel we obtain the following.

In a large plant that uses the Hot Cup Cold Draw Process 411 personnel are dedicated to Material Handling. After "modernization" the number of Material Handlers is projected to be 339.

This "modernization" does not provide for an integrated material handling system. Using an integrated handling system for a similar plant manufacturing the same production rate and the same size projectile but using the Hot Forge Heat Treatment method, contractor estimates total material handlers at 57 per shift or 171 for three shifts versus 339. Using this information, the following payback ratio is obtained.

Present Alternative — Continue Manual Transfer 339 Personnel

Proposed Alternative — Integrated Material Handling 171 Personnel

Economic Life 10 Year Basis

Program Year	Present Alternative	Proposed Alternative	Differential Cost	Discount	Discount Differential Cost
1	8,461,440	4,268,120	4,193,320	.954	4,000,427
2	8,461,440	4,268,120	4,193,320	.867	3,635,608
3	8,461,440	4,268,120	4,193,320	.788	3,304,336
4	8,461,440	4,268,120	4,193,320	.717	3,006,610
5	8,461,440	4,268,120	4,193,320	.652	2,734,044
6	8,461,440	4,268,120	4,193,320	.592	2,482,445
7	8,461,440	4,268,120	4,193,320	.538	2,256,006
8	8,461,440	4,268,120	4,193,320	.489	2,050,533
9	8,461,440	4,268,120	4,193,320	.445	1,866,027
10	8,461,440	4,268,120	4,193,320	.405	1,698,294
TOTAL					27,034,330

Direct Labor Cost with Overhead $12/Hr

$12/Hr X 2080 Hrs/Yr $24,960/manyear

$24,960/manyear X 339 men = $8,461,440/yr

$24,960/manyear X 171 men = $4,268,120/yr

Differential Cost $4,193,320/yr

Present Value of New Equipment

a. Land and Buildings 0

b. Equipment Material Handling System $6,250,000

c. Other | 0

c.	Other	0
d.	Working Capital	0
	Total Present Value of New Investment	$6,250,000

15. Less: Present Value of Existing Assets — 0

16. Value of Existing Assets — 0

17. Net Investment — $6,250,000

18. Present Value of Cost Savings from Operations — $27,034,330

19. Plus: Present Value of Cost of Refurbishment — 0

20. Total Present Value of Cost Savings — $27,034,330

21. Savings Investment Ratio (Pay Back)

    Line 20 divided by Line 17 — 4.325

Here we see that based on conservative figures and manpower requirements estimated by private contractors the payback investment ratio is greater than four. The cost of the material handling system is an actual quotation from a contractor based on buyer specifications. It is to be noted that the number of personnel, 57 per shift used here was an estimate by a private contractor and is considered conservative, therefore the actual payback ratio will probably be greater than shown here.

A study conducted under this project reveals that a similar situation exists for a centralized chip transport system which will be discussed next in this section.

D. STUDIES

1. Chip Transport Systems Study

Chip transport systems as reported from the survey have not been too successful to date. Typically chips are being placed in tote boxes and moved by forklift trucks to a central scrap area where they are then loaded on rail cars. Conversations with private industry by Frankford Arsenal engineers reveal that in recent years, centralized chip transport systems have been successful. Improved harpoon systems and flume systems are reportedly working well. One automobile plant reported writing off the cost of their centralized chip transport system in approximately fourteen months of operation. This system transported chips by use of a flume located directly under the machine tools. The chips are transported to a drag out conveyor where the transporting medium, the cutting coolant, is filtered and returned to the machine tools. The chips are sent to a crusher and then to a centralized dryer where the final residual coolant is separated from the chips. In this plant, the dried chips are then transported

by way of pneumatic tube to a hopper which empties out to an awaiting rail car. The value of chips in this condition as compared to uncrushed oil chips is considerably more. At the present time, the price is as follows:

Unprocessed — $22/Ton (Dec 75)

Processed — $38/Ton (Dec 75)

If one considers a large plant such as Lone Star Army Ammunition Plant (LSAAP) where approximately 10,140 tons of chips per month will be processed, a saving can be shown by installing a centralized system as follows. It is estimated at least thirty-one (31) personnel must be dedicated to chip transport if a centralized system is not used. This is based on actual personnel used at a Hot Cup-Cold Draw plant which moves considerably less chips. To do the same work, three personnel will be required with an integrated system. Processed chips designated "short shovel turning" are typically valued at $10 per ton more than unprocessed chips. During a situation where steel is in high demand such as a war emergency, a high demand such as in January 75, this figure easily rises above $20 per ton. Metal Working News reports for 27 Jan 75, chips delivered to crusher at $20/ton while short shovelings are valued at $48/ton in Pittsburgh. However, for this purpose, we will use the present value of $10/ton. Cost of a centralized chip handling system, complete with Crusher, Dryer, etc., is estimated at $2,700,000 based on actual quotations for a plant sized to the LSAAP configuration.

We have the following:

a. Present Alternative — Manually move chips and don't process.

b. Proposed Alternative — Used centralized chip transport system.

Economic Life — 10 Years

Program Year	Present Alternative	Proposed Alternative	Differential Cost	Discount	Discount Differential Cost
1	$2,041,440	$74,880	$1,966,560	0.954	1,876,098
2	$2,041,440	$74,880	$1,966,560	0.867	1,705,007
3	$2,041,440	$74,880	$1,966,560	0.788	1,549,649
4	$2,041,440	$74,880	$1,966,560	0.717	1,410,023
5	$2,041,440	$74,880	$1,966,560	0.652	1,282,197
6	$2,041,440	$74,880	$1,966,560	0.592	1,164,203
7	$2,041,440	$74,880	$1,966,560	0.538	1,058,009
8	$2,041,440	$74,880	$1,966,560	0.489	961,647

Program Year	Present Alternative	Proposed Alternative	Differential Cost	Discount	Discount Differential Cost
9	$2,041,440	$74,880	$1,966,560	0.445	875,119
10	$2,041,440	$74,880	$1,966,560	0.405	796,456
TOTAL DISCOUNT DIFFERENTIAL COST				—	$12,677,408

Present Alternatives — 33 personnel @ 12/hr x 2080 = $823,680/Yr

Cost of Chips (loss) $10/ton x 10148 tons/Mo. x 12 Mo. = $1,217,760

Total cost present alternative — $2,041,440

Proposed Alternative — 3 personnel @ $12/Hr x 2080 <u>$74,880/Yr</u>

Differential Cost — $1,966,560

Present Value of New Equipment — $2,700,000

Net Investment – $2,700,000

Present value of cost savings from operation — $12,677,408

Savings Investment Ratio (Payback) — $12,677,408 ÷ 2,700,000 = 4.695

Here we see that centralized chip transport systems have a high payback ratio. Further, such systems are in existence today and are working satisfactory with a minimum of downtime and maintenance. When one considers the payback ratio and the reduction in direct labor by using a centralized chip transport system, a major emphasis should be made to assure that such systems should be incorporated into existing and future facilities when feasible. It should be noted that in some cases where the chip load is small the installation cost of a centralized system may exceed the recurring costs of manual transfer and in such cases manual transfer to chip processing units should be considered.

E. CONCLUSIONS

The data collected under this report thru literature surveys, plant surveys, state of art studies and equipment manufacture visits confirms that considerable savings in manpower and costs can be realized if material flow thru the plant is studied and an intelligent material handling system is brought into operation in the plants. This system must be integrated if maximum cost benefits are to be realized. It doesn't pay, for instance, to go to the trouble of purchasing an automatic machine tool with automatic load and unload equipment and then require an operator be there to move the part to a conveyor since the advantages of the system are lost. The system must be integrated and address all movements of the workpiece from billet to painted projectile.

Automatic inspection is required to fulfill the realization of this system and to monitor proper behavior of forging and machine tool equipment. The material handling then can be considered to comprise the following areas:

a. Projectile Transport System

1. Transfer part from one operation to the next.
2. Provide adequate flow to an operation and from a preceding operation. Adequate flow is defined as production equipment pacing the material handling system through the use of buffer zones provided by banking systems.
3. Automatic transfer to and from the production equipment transport system.
4. Production equipment moves parts thru its process automatically to the automatic inspection stations and on to a transfer point to the material handling system.

b. Chip Transport System

1. Move chips away from machine tools as required.
2. Recirculate coolant after filtering
3. Crush chips
4. Dry chips
5. Transport chip to storage area for loading in rail cars.

The surveys to date indicate material handling has not been given the proper recognition in plant modernization now going on. The modernization of our plants must be more than a modernization of individual operations; it must include methods for estimating production line output subject to uncertainties of individual operations. It must be capable of providing proper buffer, live storage bank, etc. to assure proper feeding of production equipment as required; mathematical modeling of the production flow provides a tool to start such an evaluation.

F. RECOMMENDATIONS

In order to provide a basis for the introduction of efficient, reliable, and cost effective material handling systems into projectile manufacturing plants, the following studies are required:

1. Mathematical modeling of material flow for munitions production lines.

This study would develop computer models to describe the operating characteristics of production lines and simulate projectile manufacturing processes. Statistical distribution of machine failure, defective parts, buffer effects, equipment age, operating experience, line layout and other pertinent variables would be determined and identified. Simulation runs would be conducted to assess the productivity of actual manufacturing systems and determine overall reliability. Data obtained from the simulations would be used to design an optimal manufacturing system based on cost effectiveness and reliability of meeting production requirements.

An additional aspect of this study would involve a study of material handling methods and equipment. Various manufacturing plants would be contacted to observe and study existing practices. Experience with various types of devices would be analyzed for application to ammunition production lines.

The results of this study would provide the method for the optimization of existing and future production lines.

2. Chip Transportation Study

This study would obtain information on the availability of chip handling components or sub systems which can be used for the interfacing of an automatic integrated chip transporting system for artillery metal parts manufacturing plants. This would be accomplished by surveying the chip handling industry to determine what type of components or sub systems are available that can be interfaced. The components to be evaluated would be the necessary conveyor equipment to transport the turnings from a battery of machine tools, parts separating equipment for removal of foreign objects from the turnings, a crusher to reduce the turnings to chips, wringing equipment to remove the cutting fluids from the chips, coolant reclamation equipment and storage bins to allow accumulation of chips.

A comparison of the various equipment would be made which would allow the selection of the optimum components for interfacing into a highly reliable and cost effective chip handling and processing system.

The results of this study would establish the optimum equipment required for an automatic, integrated chip handling system which would reduce the cost of handling chips within a plant and increase the mill value of the segregated and processed chips.

MATERIAL HANDLING METHODS UTILIZED IN AMMUNITION METAL PARTS FABRICATIONS

PLANT A - 81MM M374

OPERATION	EQUIPMENT	MATERIAL HANDLING
Receive Steel	Forklifts and overhead crane	Steel bars are transported to shear area by forklift. 10 ton overhead crane loads roller conveyor.
Shear Mult	Mechanical Press	Bars are roller conveyed to press, then gravity fed to tote box.
Heat Mult	Westinghouse Tunnel Heater	Tote box forklifted to heater for manual feeding.
Forge	2000 Ton Maxi Press	Hot mults are manually lifted from heater and placed in upset die, manually transferred to extrude bottle die and manually transferred to extrude taper die.
Hot Coin	Worco Press	Extruded parts are manually removed from the forge press and placed on a holding table where they are manually deposited into the coin die.
Shot Blast I.D.	Pangborn Rotoblast	Parts are manually placed in circulating overhead conveyor for cooling purposes and automatically ejected into tote boxes. Tote boxes are carried by forklift to the shot blast area. Parts are manually loaded into the Rotoblast machine.

PLANT A - 81MM M374 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Shot Blast O.D.	Pangborn Rotoblast	After I.D. shot blasting the parts are manually unloaded into tote boxes and carried by forklift to the O.D. shot blast machine, dumped into a storage hopper which automatically loads the Rotoblast machine.
Drill Center Hole	Sundstrand 8A Automatic Lathe	Parts are automatically unloaded from shot blast into tote boxes which are forklifted to drill center hole operation. The pieces are manually unloaded into a lathe, machined and manually unloaded into a conveyor.
Turn for Concentricity	Sundstrand, 2A Automatic Lathe	Parts are manually unloaded from conveyor, machined and manually returned to the same conveyor.
Pickle, Bonderize and Soap Coat	Computer Operated Tank System	Parts are manually removed from conveyor into tote box and forklifted to tank system where they are manually loaded on specially designed racks. They are manually unloaded into tote bins.
1st Forward Extrude	800 Ton Warco Press	Tote bins are forklifted to press. Manually placed in press, extruded, manually unloaded onto conveyor.
2nd Forward Extrude	800 Ton Warco Press	Parts are manually unloaded into press extruded and manually returned to a conveyor.

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PLANT A - 81MM M374 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Nosing	Lake Erie Press	Parts are manually loaded into press. Manually unloaded and placed on a belt conveyor.
Stress Relieve	Inline Continuous Furnace	Parts are conveyed automatically and loaded into furnace. Parts automatically exit furnace and are gravity fed onto another belt conveyor.
Remove Center Boss	NBG Multi-Spindle Lathe	Parts are manually transferred from belt conveyor to hanger conveyor. Parts are manually unloaded into lathe and returned manually to hanger conveyor.
Bore, Face, Chamfer Nose	NBG Multi-Spindle Lathe	Parts are manually unloaded from hangers and returned to hanger conveyor.
Finish Turn O.D. & Obturator Band Groove	Sundstrand 8A Automatic Lathe	Operator unloads parts from hanger conveyor and replaces it on hanger conveyor.
Wash	Continuous Washer	Parts are manually unloaded from hanger and placed in trays which are conveyed into washer.
Braze Base Cover	Induction Unit	Trays are power roller conveyed through braze operation. Parts are manually transferred from trays to an overhead conveyor.

PLANT A - 81MM M374 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Grind Bourrelet	Cincinnati Grinder	Parts are manually removed from conveyor and ground, then manually placed on a hanger conveyor.
Turn, Face, Chamfer & Thread Base	NBG Multi Spindle Lathe	Parts are manually unloaded and manually returned to conveyor.
Thread Nose	Tapper	Parts are manually removed from conveyor and manually replaced on conveyor.
Wash	Inline Continuous Unit	Parts are conveyed thru unit.
Inspect Prior to Paint		Parts are manually removed from conveyor into trays for inspection. After inspection,
Stamp	Schmidt Stamper	pieces are stamped and manually placed on conveyor.
Bonderize	Inline Continuous Unit	Parts are conveyed thru unit.
Paint I.D. & O.D.	Inline Automatic Electro Static Unit	Parts are manually transferred from overhead conveyor to paint conveyor where they are painted and dried.
Final Inspect	Manual	Parts are manually transferred to trays, inspected and thru tray are manually unloaded and pieces placed in cartons.

PLANT B - 81MM M374

OPERATION	EQUIPMENT	MATERIAL HANDLING
Receive Steel	Overhead Crane	Crane transfers steel from carrier to storage yard. Bars are forklifted to a powered roller conveyor.
Shear	Mechanical Press	Bars are power roller conveyed to shear press, mults are gravity fed to tote box.
Shot Blast	Wheelabrator	Tote boxes are forklifted to wheelabrator; automatically loaded into wheelabrator and dumped back into tote box.
Weigh & Lube	Special Fixture	Tote boxes are forklifted to manually fed conveyor, manually unloaded and weighed, and manually fed to conveyor, through lube, and dropped into tote box.
Induction Heat	Tocco Solid State Units	Tote boxes are forklifted to induction coils, mults manually loaded to automatic coil feeder, then gravity fed from coils to holding area by forge press.
Upset & Extrude	2500 Ton Mechanical Press	Mults are manually lifted from holding area and placed in upset die, upset, then manually transferred to extrude die, extruded, then automatically ejected from press and gravity fed to belt conveyor.
Hot Coin	1600 Ton Mechanical Press	Parts are manually transferred from belt conveyor to coin press; automatically ejected from coin press; manually placed on overhead conveyor and conveyed to shot blast.

PLANT B (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Shot Blast	Wheelabrator	Parts are manually transferred from conveyor to tote box; forklifted to wheelabrator, automatically loaded into wheelabrator; dumped back into tote box.
Pickle, Bonderize, and soap coat	P.B.S. Continuous Unit	Tote boxes are forklifted to P.B.S. unit, parts are manually loaded on conveyor, conveyed through unit and onto iron.
Iron Bourrelet	300 Ton Hydraulic Press	Parts are manually transferred to and from conveyor to press, then manually transferred from press to tote box.
Wash to Remove Soap	Inline Continuous Unit	Tote boxes are forklifted to manually fed overhead conveyor; parts are conveyed through wash to automatic chucker.
Machine Closed End	8 Spindle Automatic Chucker	Parts are manually transferred from overhead conveyor to chucker; manually transferred from chucker back to conveyor.
Profile O.D.	Single Spindle Automatic Tracer Lathe	Parts are manually transferred from overhead conveyor to tracer lathes, manually transferred back to conveyor, then manually transferred to soap coat conveyor.

PLANT B (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Pickle, Bonderize and Soap Coat	Inline Continuous Unit	Parts are conveyed through unit by overhead conveyor.
Invert and Nose	200 Ton Hydraulic Press	Parts are manually transferred from conveyor to press; automatically transferred from invert die to nose die; manually transferred from nose die to tote box.
Wash to Remove Soap	Inline Continuous Unit	Tote boxes are forklifted to wash area, parts are manually transferred to overhead conveyor; conveyed through wash to stress relieve.
Stress Relieve	Inline Continuous	Parts are conveyed through stress relieve to bore, face, and chamfer, chuckers.
Bore, Face, Chamfer, and Thread Open End	6 Spindle Automatic Chucker	Parts are manually transferred from conveyor to chucker; then manually transferred from chucker to braze base cover conveyor.
Braze Base Cover	Continuous Wash, Induction Heat, Automatic Paste and Cover Applicator	Parts are manually transferred from conveyor to inline wash; manually transferred to automatic paste & disk applicator. Automatically transferred to a continuous induction system. Manually transfer to overhead conveyor.
Machine Bourrelet Obturator Groove and Boss	Single Spindle Automatic Lathe	Parts are manually transferred from overhead conveyor to lathe returned to overhead conveyor.

PLANT B (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Roll Thread on Boss Inspect Prior to Paint	Thread Roller	Parts are manually transferred from overhead conveyor to thread roller; manually transferred from thread roller to tote box. Manually carried in tote box to inspection. After inspection manually carried in tote box to stamp.
Stamp Nomenclature	Roller Marker	Parts are manually removed from tote box to stamp; manually transfer to overhead conveyor to paint.
Paint	Inline Automatic	Parts are manually transferred from overhead conveyor to paint conveyor; Painted, dried, and manually inserted in shipping containers for inspection.
Final Inspection	Manual	Parts are roller transferred in shipping box to final inspection; roller transferred to packing station.
Pack	Manual	Packed parts are manually transferred to pallets; pallets are forklifted to shipping area.
Ship	---	Pallets are forklifted onto trucks for shipment.

PLANT C - 105MM M1

OPERATION	EQUIPMENT	MATERIAL HANDLING
Receive Steel	Overhead Crane	Overhead crane transfers steel from carrier to storage yard.
Nick	Gang Welding Torches	Billets are moved from overhead crane to chain conveyor into building. Manually transferred by overhead crane to second conveyor to nick. It is transferred by overhead crane to break conveyor and rolls automatically to break.
Break	345 Ton Press	Stock rolls to break die; gravity fed to tote box; fork lifted to forge building.
Heat Mults	Rotary Furnace - Gas & Oil	Mults are manually transferred from tote box and loaded into furnace (hand tongs); manually unloaded to gravity chute.
Descale	Water Blast	Mults are gravity fed through descaler to forge press.
Size and Pierce	325 Ton Press	Parts are manually loaded and unloaded into forging operation, then transferred manually to draw.
Draw	75 Ton Press	Parts are manually loaded and unloaded and placed on overhead conveyor to center base.
Center Base	Automatic Lathe	Parts are transferred manually from conveyor to lathe and onto a roller type power conveyor leading to a rough turn operation.

PLANT C - 105MM M1 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Rough Turn	Automatic Lathe	Parts are manually loaded and unloaded to a gravity fed conveyor.
Lube and Nose	300 Ton Press	Parts are gravity conveyed through lube and automatically dumped into nose press; manually transported to roller type spur conveyor and automatically loaded to saddle type conveyor.
Heat Treat	Gas Fired Furnace	From a saddle type conveyor, the part is conveyed through the furnace and is manually unloaded and transferred to external overhead conveyor.
Hardness Inspect	Detroit Tester	Parts are manually loaded and unloaded at hardness station; conveyed to shot blast.
Shot Blast	Pangborn Pressure Blast	Parts are manually transferred to roller conveyor. Then shell is loaded manually to shot blast and transferred to second roller conveyor.
Bore, Face and Chamfer	Automatic Lathe	Parts are manually loaded and unloaded and transferred back to roller conveyor; auto transferred to dumbwaiter to first floor; transferred autcmatically from dumbwaiter to roller conveyor.
Finish Turn	Automatic Lathe	Parts are manually loaded and unloaded and returned to roller conveyor.

PLANT C - 105MM M1 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Face, Base, and Boattail	Automatic Lathe	Parts are manually loaded and unloaded and returned to roller conveyor.
Turn Band Groove	Automatic Lathe	Parts are manually loaded and unloaded and reuturned to roller conveyor.
Knurl Band Groove	Automatic Knurling Machine	Parts are automatically loaded from roller conveyor and automatically unloaded to gravity fed conveyor.
Rough and Finish Grind	Centerless Grinder	Parts are gravity fed through rough and finish grinders; automatically ejected from finish grinder to conveyor.
Weld Base Plate	Resistance Welder	Parts are automatically loaded and unloaded to a lower conveyor.
Thread Nose	Tapper	Parts are automatically loaded and unloaded back to conveyor.
Press Rotating Band	West Tire Setter	Parts are manually loaded, unloaded, and returned to conveyor.
Turn Band	Automatic Lathe	Parts are manually loaded, unloaded, and returned to conveyor.
Mark I.D.	Matthew Marker	Parts are automatically loaded, unloaded and transferred to conveyor.
Final Inspect	Gages	Parts are manually loaded and unloaded and transferred to saddle type overhead conveyor.

PLANT C - 105MM M1 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Wash and Bond	Ranshoff System	Parts are conveyed through system to paint.
Paint and Ship	Paint Booth	Parts are manually transferred from saddle conveyor to paint conveyor; conveyed through paint; manually unloaded and transported to saddle conveyor to package; manually unloaded at pack.

PLANT D - 105MM M1

OPERATION	EQUIPMENT	MATERIAL HANDLING
Receive Steel	Overhead Crane	Overhead crane transfers bar from the storage area to defrost oven.
Defrost Bar Stock	Bar Defroster	Bars are conveyed through the oven; unloaded by an overhead crane and transferred to the saws.
Saw Mults	Automatic Band Saw	Bars are loaded by an overhead crane: after sawing the mults are automatically gravity fed to a power conveyor.
Descale	Wheelabrator	Mults are powered conveyed to the wheelabrator; automatically loaded and then both manually unloaded and forklifted to a first induction heater and automatically unloaded and power conveyed to a second induction heater.
Heat Billet	Induction Heater	Mults are manually loaded into first induction heater and automatically loaded into second induction heater. Mults are automatically unloaded from both heaters.
Forge (Block, Cabbage, and Pierce)	Mechanical Press	Parts are automatically transferred through the three station press and gravity fed through a trough.
Quench Base	Special Fixture	Parts are automatically transferred to a powered conveyor and conveyed through the quench system; automatically unloaded and transferred to a powered conveyor.

PLANT D - 105MM M1 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Retard Cool	Retard-Cooling Oven	Parts are conveyed through the oven and automatically transferred to the descale conveyor.
Descale	Wheelabrator	Parts are conveyed through the wheelabrator; automatically unloaded and transferred to the rough turn conveyor.
Rough Turn, Boat-tail, O.D. & Face Base	Automatic Lathe	Parts are manually loaded and unloaded from the lathes and returned to the power conveyor (roller).
Pickle, Phosphate and Lube	Tank System	Parts are automatically transferred to a hanging conveyor and conveyed through the tank system; the parts are automatically unloaded and transferred to an overhead conveyor.
Cold Draw	Horizontal Press	Parts are automatically loaded and unloaded from the press and automatically transferred to an over-head conveyor.
Trim to Length	Automatic Lathe	Parts are automatically loaded and unloaded from the lathes and automatically transferred to the lubri-cation conveyor.
Pre-Coin Lube	Special Fixture	Parts are conveyed through the lubrication system to the coin presses.
Coin Base & Pre-form Front Bour-relet	Horizontal Dial Press	Parts are automatically loaded, unloaded, and gravity conveyed to the nosing presses.

PLANT D - 105MM M1 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Nose	Horizontal Dial Press	Parts are automatically loaded, unloaded, and automatically transferred to a power conveyor.
Wash and Stress Relief	Washer and Stress Relief Furnace	Parts are automatically loaded from the power conveyor and automatically unloaded on to a gravity conveyor.
Deburr	Special Fixture	Parts are manually loaded and unloaded from a gravity conveyor.
Centerless Grind	Cincinnati Grinder	Parts are manually loaded from a gravity conveyor; automatically unloaded onto a gravity conveyor and automatically transferred to an overhead conveyor.
Bore, Face, Chamfer, & Turn Band Grooves	Automatic Lathe	Parts are automatically transferred from an overhead conveyor to a gravity conveyor; manually loaded and unloaded from the lathes to a gravity conveyor.
Knurl Band Grooves	Knurling Machine	Parts are manually loaded and unloaded from a gravity conveyor.
Tap Nose	Cleveland Tapper	Parts are manually loaded and unloaded from a gravity conveyor.

OPERATION	EQUIPMENT	MATERIAL HANDLING
Clean and Dry	Carousel Washer	Parts are manually transferred from a gravity conveyor; conveyed through washer and manually unloaded onto a gravity conveyor and automatically transferred to an overhead conveyor.
Weld on Base Cover	Banner Welder	Parts are automatically transferred from an overhead conveyor to a gravity conveyor automatically loaded and unloaded from the welder onto an overhead conveyor.
Assemble Band	Hydraulic Banding Press	Parts are automatically loaded and unloaded from the banding press and automatically transferred to an overhead conveyor.
Turn Band	Automatic Lathe	Parts are automatically transferred from an overhead conveyor to a gravity conveyor. The part is manually loaded and unloaded from the lathes and returned to the gravity conveyor.
Mark Shell	Marking Machine	Parts are manually loaded and unloaded from the marking machine and transferred to a gravity conveyor.

PLANT D - 105MM M1 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Clean, Phosphate and Dry	Automatic Washer with Multi-Station Dryer	Parts are manually loaded and unloaded from the phosphate machine and manually transferred to the paint station.
Paint	Multi-Station Spray Booth	Parts are manually loaded and unloaded from the paint booth and manually placed on pallets.
Palletize and Ship	Special Fixture	The loaded pallets are manually pushed on a roller conveyor to the banding station. After banding the pallets are forklifted to rail cars.

PLANT E - 155MM M107

OPERATION	EQUIPMENT	MATERIAL HANDLING
Receive Steel	Overhead Crane	Overhead crane lifts bars to central billet nicking system.
Nick Bar	Central Avico Nicking Machine	Bars are gravity fed from receiving platform to automated nicking station.
Break Billet	Lake Erie 200 Ton Breaking Press	Bars are power roller conveyed to break press. After breaking, mults are weighed, then conveyed automatically on a roller conveyor to the heating furnaces.
Heat Mults	Surface Combustion Rotary Gas Fired Furnace	Mults are automatically loaded and unloaded from a powered roller conveyor.
Descale	Hydraulic Descaler	Powered roller conveyor transfers mults horizontally through water descaler.
Cabbage	800 Ton Erie Hydraulic Press	Parts are automatically loaded and unloaded through press by mechanical manipulator.
Pierce	800 Ton Erie Hydraulic Press	Parts are automatically loaded and unloaded through press by mechanical manipulator.
Draw	400 Ton Erie Hydraulic Press	Parts are automatically loaded and unloaded through press by mechanical manipulator.
Slow Cool Furnace	Cooling Tunnel	Parts are manually loaded onto cooling quills which are driven automatically through cooling tunnel. Presently manually unloaded to roller conveyor.

PLANT E - 155MM M107 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Shot Blast I.D. and O.D.	Pangborn Equipment	Parts are manually rolled off conveyor. Manually loaded and unloaded from shot blast cabinets.
Center and Cutoff	P and B Lathe	Manually operated floor mounted jib crane with jaw grab lifts and swings parts from conveyor to machine and back.
Rough Turn	Barney Lathe	Manually operated floor mounted jib crane with jaw grab lifts and swings parts from conveyor to machine and back.
Heat Nose	Surface Combustion Gas Fired Furnace	Parts are received at nosing furnaces via roller conveyor. Furnace operator rolls parts to front of furnace. Operator pushes parts nose first into port of rotary nosing furnace. Operator of furnace pushes shells from furnace port with manual tong and places shell base first on gravity conveyor to nose press.
Nose	350 Ton Hydraulic Lake Erie Press	Gravity conveyor transports parts from heat nose to nosing press. Operator on opposite side of press picks up parts from lower platform with jib crane lift and places shell in skids nose down.
Heat Treat	Surface Combustion Overhead Suspension Type	Parts are manually loaded and unloaded from hanger by elevating parts in skids on elevator.

PLANT E - 155MM M107 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Accelerated Cooling	Cooling Conveyors	Parts are manually loaded and unloaded by air tongs to roller conveyor.
Shot Blast	American Wheelabrator	Parts are received at shot blast cabinets on roller conveyor. Parts are loaded in shot blast by automatic up ender and air cylinder pusher. Parts are unloaded automatically to roller conveyor.
Hardness Test	Brinnel Hardness Tester	Operator pushes parts through 100% hardness check.
Bore, Face, and Chamfer	Jones and Lamson Fay Lathe	Manually operated floor mounted jib crane lifts and swings parts from conveyor to machine and back.
Saw Boss	Marvel Heavy Duty Sawing Machine	Operator pushes parts off line conveyor to saws and back to conveyor for advance to next operation.
Finish Turn, Body and Ogive	Stamets No. 2R Shell Turning Machine	Operator pushes parts off line to take away conveyor to feed machine. Manually loaded and unloaded by operator. After machining, parts are pushed off conveyor for advance to next operation.
Weigh Shell	Scale	Parts are manually loaded and unloaded from inline scale.

PLANT E - 155MM M107 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Turn Boattail and Face Base	P and B Special Single Purpose Shell Turning Machine	Operator pushes parts off line to take away conveyor to feed machine. Parts are manually loaded and unloaded by operator. After machining parts are pushed off conveyor for advance to next operation.
Turn Band Seat, Dovetail and Knurl	P and B Special Single Purpose Shell Turning Machine	Operator pushes parts off line to take away conveyor to feed machine. Parts are manually loaded and unloaded by operator. After machining, parts are pushed off conveyor for advance to next operation.
Grind Bourrelet	Cincinnati #2 Centerless Grinder	Grinding machine is directly over conveyor. Operator pushes parts into grinding position. After completion of rotational grinding operation, operator advances parts on conveyor.
Tap Nose	Landis Thread Tapper	Operator rolls parts from horizontal line conveyor onto machine and into machine cradle. Operator pushes parts back to line conveyor for advance to next operation.
Press Band	West Tire Setter	Operator rolls parts from line conveyor to handling press and returns the same way to conveyor for advance to next operation.

PLANT E - 155MM M107 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Machine Band	P and B Special Purpose Turning Machine	Operator pushes parts off line to take away conveyor to feed machine. Parts are manually loaded and unloaded by operator. After machining parts are pushed to conveyor for advance to next operation.
Weld Base Cover	Taylor Winfield Horizontal Air Operated Seam Welder	Operator rolls parts from horizontal conveyor into driven and idling rollers. After welding parts are pushed to conveyor for advance to next operation.
Stamp Nomenclature	Noblewest Dial Marking Machine	Operator up ends parts to vertical position, nose up. Slides parts on base into marking machine which runs continually. Parts automatically eject from machine after marking. Operator lays parts in horizontal position and places on conveyor for next operation.
Clean and Bonderize	Dextrex Spray Rinsing Unit	Horizontal line conveyor feeds parts onto gravity roll feeder station. Operator feeds parts one at a time into automatic loading device. Parts pass through enclosed unit on monorail conveyor and unloads to roller conveyor.

PLANT E - 155MM M107 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Paint I.D.	Devilbiss Paint Spray Unit	Parts are pushed into power driven rolls to index of spray nozzle. Parts are automatically ejected to roller conveyor.
Paint O.D.	Devilbiss Paint Spray Unit	Operator inserts nose lifting plugs and rotating band grommets. Nose plug of parts are attached to monorail chain hook which transports parts vertically through paint O.D. station.
Palletize and Strap	--	Manual

PLANT F - 155MM M107

OPERATION	EQUIPMENT	MATERIAL HANDLING
Receive Steel	Overhead Crane	Bars are lifted by overhead crane to chained conveyor roller platform.
Nick Bar	Arc Welder-- Oxweld Acetylene	Bars are gravity fed from receiving platform to nick table.
Break Billet	Watson Stillman 350 Ton Press	Bars are gravity roller conveyed to break press. After breaking, mults are weighed then gravity fed on a manually pushed roller conveyor to steel skids. Skids are transferred to storage area by forklift.
Heat Mult	Jet Combustion 20' Rotary Furnace	Forklift truck transfers skids to storage table prior to heat. Pneumatic pusher removes mults from skids to power roller conveyor which feeds gravity conveyor prior to heating furnace. Mults are loaded and unloaded by manually operated mechanical manipulator to power chain conveyor.
Descale Mult	Water Descaler	Powered roller conveyor transfers mults horizontally through hydraulic descaler. After descale mults are upended into circular pot.
Pierce Mult	500 Ton Press	Mults are loaded and unloaded by manually operated mechanical manipulator to next forming operation.

PLANT F - 155MM M107 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Draw	Horizontal Draw Press	Parts are loaded and unloaded by manually operated mechanical manipulator to powered chain conveyor.
Cool Forging	Jet Combustion Cooling Furnace	Powered chain conveyor transfers parts through slow cool furnace.
Shot Blast	Pangborn Four Hole Shot Blast	Parts are manually rolled off conveyor. Manually loaded and unloaded from shot blast cabinets.
Center and Cutoff	Sundstrand, Cross	Machine tool operator manually loads and unloads machine by pushing parts off of conveyor into machine tool and back onto conveyor.
Rough Turn	Sundstrand, Cross, Barney	Machine tool operator manually loads and unloads machine by pushing parts off of conveyor into machine tool and back on.
Heat Nose	Johnson Gas Fired Continuous	Parts are automatically fed on a power conveyor through the in-line heating furnace.
Nose	Elmes Hydraulic Press	Manually operated mechanical manipulator removes parts from conveyor and loads nosing press.
Heat Treat	Chicago & Stewart Furnace	Gravity conveyor from nosing press feeds heat treat furnace. Manually operated air tongs place parts in a rotary austenitize furnace (Chicago) or on a walking beam through furnace (Stewart).

PLANT F - 155MM M107 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Heat Treat		Load and unload between austenize quench, and temper in the rotary system is accomplished by manually operated air tongs. A walking beam transfers the parts through the austentize quench and temper of the straight through heat treat system. Gravity conveyor from cooling furnace feeds roller conveyor.
Test Hardness	Detroit Hardness Tester	Parts are manually pushed through the hardness check.
Shot Blast	Pangborn - 4 Hole Blast Cleaning Machine	Parts are manually rolled off conveyor and manually loaded and unloaded from shot blast cabinets.
Bore, Face, and Chamfer	Barney Lathe	Machine tool operator manually loads and unloads machine by pushing parts off conveyor into machine tool and back on conveyor.
Finish Turn	Sundstrand Barney Cross	Machine tool operator manually loads and unloads machine by pushing parts off conveyor into machine tool and back on conveyor.
Cut Off Boss	Power Hack and Band Saws	Machine tool operator manually loads and unloads machine by pushing parts off conveyor into machine tool and back on conveyor.

PLANT F - 155MM M107 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Turn Boattail and Face Base	Barney Lathe	Machine tool operator manually loads and unloads machine by pushing parts off conveyor into machine tool and back onto conveyor.
Turn Bandseat and Dove Tail	Barney Lathe	Machine tool operator manually loads and unloads machine by pushing parts off conveyor into machine tool and back onto conveyor.
Tap Nose	Landis 4 Chaser Tapper	Machine tool operator manually loads and unloads machine by pushing parts off conveyor into machine tool and back on conveyor.
Knurl Band Seat	Schmidt Knurler	Parts are manually pushed off powered convey-or to the take off convey-or which feeds knurler and returned to exit conveyor by operator.
Grind Bourrelet	Cincinatti Center-less Grinder	Grinding machine is located directly over conveyor. Operator pushes parts into grinding position.
Apply Band	West Tire Center	Parts are manually pushed off powered convey-or to take off conveyor which feeds banders and returned to exit conveyor by operator.
Weld Base Cover	Welder	Machine tool operator manually loads and unloads machine by pushing parts off conveyor into machine tool and back on conveyor.

PLANT F - 155MM M107 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Turn Band	Barney Lathe	Machine tool operator manually loads and unloads machine by pushing parts off conveyor into machine tool and back on conveyor.
Mark Shell	Matthew Automatic	Marking machine is located directly over conveyor. Operator pushes parts into marking position.
Bonderize	Detrex Corp. Unit	Horizontal line conveyor feeds parts into gravity roll feeder station. Parts pass through the enclosed unit on a monorail conveyor.
Paint Shell I.D.	Brinks Spray Booth	Parts are on roller conveyor in horizontal position from previous operation. Operator inserts thread and band covers in each part. Parts are rolled on covers into power driven rollers to index of spray nozzle for I.D. Paint. Operator removes thread cover and inserts nose lifting plugs.
Paint Shell O.D.	Binks Painting Unit	Nose lifting plug is manually attached to monorail chain hook which transports parts vertically through paint O.D. station
Palletize & Strap	None	Manual

PLANT G 155MM M107

OPERATION	EQUIPMENT	MATERIAL HANDLING
Receive Steel	Overhead Crane	Overhead crane transfers steel from carrier to storage yard and onto walking beam.
Mark Mult Lengths	Length Gage and Chalk	Walking beam transfers bars through mark and onto nick.
Nick for Break	400 AMP Welder	Walking beam transfers bars through nick, nicked bars are automatically transferred to power conveyor.
Break	Mechanical Press	Bars are conveyed to break. Mults are manually transferred with magnetic crane to tote box and forklifted to power conveyor.
Heat Mult	Furnace (rotary)	Mults are lifted out of tote box by magnetic crane onto a power conveyor. Automatic mechanical manipulators remove part from conveyor and deposits billet in furnace.
Descale Mult	Water descaler	Manipulator automatically enters furnace, grasps part, retracts and drops part onto gravity chute thru water descale.
Cabbage & Pierce	2500 Ton Mechanical Press	Parts are automatically loaded and unloaded by a mechanical manipulator.

PLANT G 155MM M107 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Draw	500 Ton Hydraulic Press	Parts are automatically loaded and unloaded through press by mechanical manipulator. Parts exit draw station down a gravity chute to a power roller conveyor.
Cool	Cooling Conveyor	Air cylinder pushes parts into an open cradel suspended monorail conveyor for cooling. Cooled parts are manually pushed off cradel onto a power conveyor.
Shot Blast	Multiple Station Indexing Table Shot Blast	Parts are transferred from power conveyor to shot blast by mechanical manipulator. Manipulator unloads shot blasted parts onto gravity conveyor, manually transferred to overhead conveyor, manually unloaded and guided onto a power roller conveyor.
Center & Trim in Length	Sundstrand 8A Lathe	Operator slides parts from power conveyor to spurs that enter and exit machines.
Rough Turn Outside Face, Base and Form Boss	Sundstrand 8A Lathe	Operator slides parts from power conveyors to spurs that enter and exit machines.
Apply Lube for Nosing	Spec. Spray,Unit	Parts are power conveyed through unit.
Heat for Nosing	Westinghouse Induction Heaters	Parts are manually pushed into induction heaters and exit into gravity conveyors.
Form Nose	350 Ton Press	Operator pushes parts down a gravity conveyor to a power roller to heat treat.

PLANT G 155MM M107 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Heat, Quench, Temper	Heat Treat System	Parts approach furnace on a power conveyor; loaded by manually operated power tongs and hung suspended by undercut on boss.
Shot Blast O.D.	Slinger Type, Skew Roll Shot Blast Machine	Parts are removed by same type tongs and placed on a power conveyor to a table; removed by a forklift truck and laid on floor to cool.
Shot Blast Cavity	Multi-Station, Indexing Table, Air Type, Shot Blast Manual Load Unloader Hoist Assist.	Parts are forklifted to shot blast and exit on power conveyor.
Remove Heat Treat Boss	Press Mechanical Spec. Tool	Parts exit shot blast machines on a power conveyor to a gravity conveyor which feeds a press for boss removal. Parts exit on a power conveyor to bore, face and chamfer.
Bore, Face and Chamfer Nose	Multi Station Automatic XLO Parker Boring Machine	Parts approach machine on a power conveyor; Parts are automatically loaded and unloaded and returned to a power conveyor.
Finish Turn Outside (Except Boattail)	Hydra-Feed HD-12 Lathe Between Center	Parts approach lathe on a power conveyor, slid manually in and out of lathe onto a power conveyor and proceed to next operation.

PLANT G 155MM M107 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Machine Base and Boattail	Hydra-Feed HD-12 Lathe Hollow Spindle	Parts approach lathe on a power conveyor, slid manually in and out of lathe onto a power conveyor and proceedsto the next operation.
Tap Nose Thread	Landis Tapper	Parts approach lathe on a power conveyor, slid manually in and out of lathe onto a power conveyor and proceed to the next operation.
Clean Cavity	Auto. Spec. Flusher	Parts approach machine on a power conveyor, slid manually in and out of machine on a power conveyor and proceed to next operation.
Machine Rotating Band Groove	Hepburn Lathe, Hollow Spindle	Parts approach machines on a power conveyor, slid manually in and out of machine onto a power conveyor and proceed onto the next operation.
Knurl Band Groove Ribs	Matthews Knurler	Parts approach machines on a power conveyor, slid manually in and out of machine onto a power conveyor and proceed onto next operation.
Grind Bourrelet	Cincinnati Centerless Grinder	Parts approach grinder on a power conveyor, slid manually in and out of grinder, onto a power conveyor and proceed onto the next operation.

PLANT G 155MM M107 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Weld Base Cover	Thomson Seam Welder Old Machines Retained New Machines in Line	Parts approach welder on a power conveyor, slid manually in and out of welder onto a power conveyor and proceed onto the next operation.
Press Rotating Band into Groove	Band Seater, Segment, Jaw Type, Hydraulic Watson	Parts approach seater on a power conveyor, slid manually in and out of machine onto a power conveyor and proceed on to the next operation.
Machine Band	Hepburn Lathe Hollow Spindle	Parts approach machines on a power conveyor, slid manually in and out of machine onto a power conveyor and proceed onto the next operation.
Mark Nomenclature	Matthews Marker	Parts approach marker on a power conveyor, slid manually in and out of marker onto a power conveyor and proceed to the next operation.
Phosphate	Hewitt-Robbins, Spray	Parts are manually removed from conveyor, placed in baskets and conveyed through unit.
Paint Cavity	Automatic Paint Unit Incld. Mask Thread and Unmask	Parts are manually transferred from baskets and conveyed through unit.
Paint Exterior	Automatic Paint Unit and Spray Booth	Parts are manually oriented and automatically transferred and conveyed through unit. Parts are manually unloaded and transferred to next operation.
Inspect	Manual	Manual
Pack	--	Manual

PLANT II - 175MM M437

OPERATION	EQUIPMENT	MATERIAL HANDLING
Receive Steel	Overhead Crane	Overhead crane lifts bars to central receiving platform for feed to flame cut.
Billet Separation	Artco Flame Billet Cutter	Bars are gravity fed from receiving platform to automatic flame cutting system.
Weigh Mult	Scale	Mults are automatically loaded and unloaded through scale.
Heat Mult	Selas Rotary Gas Fired Furnace	Powered roller conveyor transports parts to furnace. Furnace is loaded and unloaded by automatic mechanical manipulator.
Descale Mult	Water Descaler	Powered roller conveyor transports parts horizontally through water descaler.
Cabbage	1000 Ton Hydraulic Press	Parts are automatically loaded and unloaded through press by mechanical manipulator.
Pierce	1200 Ton Hydraulic Press	Parts are automatically loaded and unloaded through press by mechanical manipulator.
Draw	500 Ton Hydraulic Press	Parts are automatically loaded and unloaded through press by mechanical manipulator.
Cool Forging	Sunbeam Controlled Cooling Oven	Parts are powered roller conveyed to cooling oven. Pneumatic pusher removes parts from conveyor to coolerator transport.

PLANT H - 175MM M437 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Shot Blast O.D. and I.D.	Pangborn Shot Blast	Parts are automatically loaded and unloaded to internal shot blast cabinets. Powered roller conveyor transports parts through in-line O.D. shot blast cabinets.
Center & Cutoff	Gisholt Lathe	Automatic overhead robot arm transfers part from incoming conveyor to machine tool, part is automatically loaded and unloaded from machine and robot arm transfers part to outgoing conveyor.
Contour Turn	J and L Lathe	Automatic overhead robot arm transfers part from incoming conveyor to machine tool, part is automatically loaded and unloaded from machine and robot arm transfers part to outgoing conveyor.
Lube and Heat for Nosing	Spray and Induction Heat Units	In-line conveyor transports shells automatically through spray lube cabinets and induction heat coils.
Warm Nose	1000 Ton Hydraulic Press	Automatic load and unload through press by mechanical manipulator.
Heat Treat	Pacific Gas Furnace	Mechanical Manipulator picks up shells and places them in a basket conveyed through entire heat treat operation. Shells are unloaded by mechanical manipulator to powered roller conveyor.
Shot Blast O.D.	Pangborn Shot Blast	Powered roller conveyor transports shells through in-line O.D. shot blast cabinets.

PLANT H - 175MM M437 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Hardness Check	Automatic Readout Hardness Tester	Powered roller conveyor transports shells through in-line automatic hardness tester.
Bore, Face & Chamfer	7 Station Arcadia Lathe	A walking beam transfer moves shells through the multi-station machine tool.
Finish Turn	J and L Lathe	Automatic overhead robot arm transfers part from incoming conveyor to machine tool, part is automatically loaded and unloaded from machine and robot arm transfers part to outgoing conveyor.
Mill Base & Tap	5 Station Arcadia Lathe	A walking beam transfer moves shells through the multi-station machine tool.
Turn Band Seat and Obturating Band Groove	J & L Lathe	Automatic overhead robot arm transfers part from incoming conveyor to machine tool, part is automatically loaded and unloaded from machine and robot arm transfers part to outgoing conveyor.
Knurl Band Seat	Automatic Schmidt Knurling Machine	Shell is automatically transferred through knurling heads.
Weld Base Cover	Thompson-Gibb Automatic Electric Seam Welder	Base plates are automatically fed into position on the machine. Shell is automatically fed through resistance welders.
Grind Bourrelet	Cincinnati Automatic Centerless Grinder	Shell is transferred on powered roller conveyor through the automatic in-line centerless grinder.

PLANT H - 175MM M437 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Swage Band	Lawtomatic Banding Press	Shell is transported horizontally through the hydraulic banding press. Cold band blanks are automatically fed into position on the press.
Rough Turn Band	J & L Lathe	Automatic overhead robot arm transfers part from incoming conveyor to machine tool, part is automatically loaded and unloaded from machine and robot arm transfers part to outgoing conveyor.
Finish Turn Band	J & L Lathe	Automatic overhead robot arm transfers part from incoming conveyor to machine tool, part is automatically loaded and unloaded from machine and robot arm transfers part to outgoing conveyor.
Surface Treat	Alvey-Ferguson Equipment	Powered conveyor moves shells to load platform. Shells are automatically loaded on hangers for transport through the surface treat.
Paint Cavity	Bink Paint and Oven	Thread shields are manually inserted in each shell. Powered conveyor moves shell to drive rolls of automatic paint station.
Paint O.D.	Bink Paint and Oven	Nose lifting plugs and grommets are manually inserted on shells. Nose plug of shell is automatically attached to monorail chain hook which transports shells vertically through paint O.D. station.

PLANT H - 175MM M437 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Pack and Strap	Signode Bander	Projectiles are palletized six (6) rounds per pallet and automatically banded for shipment.

PLANT I - 8 INCH M106

OPERATION	EQUIPMENT	MATERIAL HANDLING
Receive Steel	Overhead Crane	Overhead crane transfers bar from carrier to storage yard and onto roller conveyor to shear press.
Billet Separation	Mechanical Press or Flame Cutting Equipment	Bar is automatically loaded in shear press and automatically ejected to roller conveyor (power).
Heat Billet	Induction System	Parts are conveyed through induction heat to gravity fed conveyor.
Size Billet and Descale	Sizing Rollers	Parts are gravity fed to size rollers; automatically unloaded and transferred to hot cup by robot arm.
Hot Cup	1000 Ton Hydraulic Press	Parts are automatically loaded by robot arm; automatically unloaded by second arm to powered roller conveyor.
Cool	Spray Cabinet	Parts are conveyed to overhead conveyor; automatically loaded to conveyor and conveyed through spray to shot blast, manually unloaded by power tongs.
Shot Blast	Roto Blast Cabinet	Parts are loaded and unloaded by power tongs and transferred to roller conveyor; conveyed to overhead conveyor; automatically loaded onto overhead conveyor, conveyed to roller conveyor, conveyed to machine cup operation.

PLANT I - 8 INCH M106 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Machine Cup	Automatic Lathe	Parts are automatically loaded and unloaded from roller conveyor conveyed to overhead conveyor automatically loaded on overhead conveyor and conveyed to lubrication system.
Lubricate Cup	Tank System	Parts are conveyed through lubrication system to forward extrude.
Forward Extrude	2000 Ton Hydraulic Press	Parts are automatically loaded and transferred into press by robot arm; Unloaded and transferred to overhead conveyor by second robot arm.
Phosphate and Lube	Tank System	Parts are conveyed through lube system to coin base.
Coin Base	3500 Ton Hydraulic Press	Parts are automatically transferred and loaded into press by robot arm; Unloaded and transferred to overhead conveyor to second robot arm.
Draw	1000 Ton Hydraulic Press	Parts are automatically transferred and loaded into press by robot arm; ejected at bottom of press. Roller conveyed to next operation.
Expand Bourrelet, Face Chamfer, and Anneal Nose	Automatic Nine Station Transfer Machine with Induction Heating Equipment.	Parts are automatically loaded and transferred through each station by walking beam; automatically transferred to overhead conveyor to phos-lube.

PLANT I - 8 INCH M106 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Phos-lube	Tank System	Parts are conveyed through phos-lube to nose operation.
Nose	1200 Ton Hydraulic Press	Parts are automatically transferred and loaded by robot arm; unloaded and transferred to overhead conveyor by second robot arm.
Grind Bourrelet	Centerless Grinder	Parts are conveyed through grinder by roller conveyor to transfer lathes.
Bore, Face Chamfer, Tap Nose, Rough and Finish Turn Band Seat, Knurl Band Seat	Fourteen Station Automatic Transfer Lathe	Parts are automatically transferred from roller conveyor and conveyed through each station by walking beam; Automatically transferred to roller conveyor and conveyed.
Apply Band	West tiresetter	Parts are manually moved from roller conveyor to tiresetter by floor mounted portable crane manually transferred to second roller conveyor; conveyed to machine band operation.
Machine Band	Automatic Lathe	Parts are automatically transferred to lathe and returned to conveyor.
Weld Base Cover	100 KVA Seam Welder	Base Plates are automatically fed into position on the welder, shell is automatically transferred to the welder and returned to roller conveyor.

PLANT I - 8 INCH M106 (CONT'D)

OPERATION	EQUIPMENT	MATERIAL HANDLING
Mark I.D.	Marking Machine	Parts are conveyed through marking machine and on to surface treat.
Surface Treat (Pre-Paint)	Tank System	Parts are manually transferred to over-head conveyor; conveyed through surface treat; manually unloaded and transferred to interior paint by roller conveyor.
Interior Paint	Spray Machine	Parts are conveyed through spray machine by roller conveyor then manually unloaded and transferred to lifting plug and assemble area.
Assemble Lifting Plug and Exterior Paint	Spray Booth	Lifting plugs are manually assembled to projectile; projectile is manually loaded and unloaded from exterior paint conveyor.
Palletized and Ship	Manual and Fork-lift	Shells are manually palletized and forklifted to boxcars for shipment.

SECTION SIX

INSPECTION

A. INTRODUCTION

A vital part of any manufacturing line is the inspection system used to maintain process control and product quality. Although the ultimate aim of the system is to assure that specified product quality levels are attained, the method and adequacy of inspection impacts other production functions in satisfying this objective. Such functions as processing raw material, material handling, rework, equipment availability and productivity itself are significantly influenced by the inspection system which highlights its overall importance as an integral part of the production system.

In view of the important role inspection plays in the production of artillery metal parts, attempts to define a meaningful modernized system can only be made after all aspects of current manufacturing processes are completely understood. Each operation in the process must be considered in conjunction with the inspection and tests performed. Such factors as the use of inspection to prevent catastrophic loss of equipment (because of grossly out-of-tolerance parts entering a particular operation), traceability of defective parts back to the machines producing them, the release and flow of parts from one operation to another, the handling of scrap and rework, determination of trends for the various operations, the acceptability of final product are just some of the items impacted by the inspection system which must be considered. Of equal importance is the method of test/inspection, the frequency of test, types of personnel performing inspection duties and the methods used to analyze the data. This is particularly true when converting to modernization systems where automation is of prime importance.

In terms of automation, serious consideration must be given to the "state-of-the-art" of inspection/testing equipment technology, economics in terms of investment costs vs. labor savings, adopting current or new methods of determining acceptability etc. such that the inspection system, as an integral part of the manufacturing line will maintain the required degree of process control and product assurance while at the same time be compatible with the continuous flow, automated production lines in modernized artillery facilities.

B. FINDINGS

As stated previously, in order to properly establish inspection needs for the future manufacture of artillery metal parts, it was necessary to first review and evaluate current methods of inspecting those items scheduled to be produced in

modernized facilities. Accordingly, a number of artillery metal parts manufacturing plants were visited for the purpose of completely documenting all aspects of inspection from incoming receiving inspection to final inspection of outgoing packaged product. During these visits, such items as the type and method of inspection, frequency of test, process and final acceptance inspection operations and the number and types of personnel performing inspections were completely documented. A total of 6 plants were visited involving four types of ammunition items.

A review of inspection procedures employed by current procedures showed that in almost all cases, manual/visual methods were employed. Also, the current processes for artillery metal parts involve essentially four levels of inspection: a machine operator inspection, a process quality control inspection, a final acceptance inspection in accordance with Government technical data requirements and a Government verification inspection.

At the machine tool level the operator monitors the output of his machine. By using hand gages, he is able to determine how well his machine is performing and when necessary adjustments are required. In this case, the frequency of inspection is based on a combination of factors such as technical data acceptance quality levels, machine accuracy, experience, etc., to assure acceptability of the final product. Usually this frequency varies from one-in-three to one-in-ten parts produced but can go as high as one-in-fifty or sixty depending on the operation and characteristics involved.

This inspection is considered to be very important in that it is the only phase where defective products can be immediately removed from the line and corrective action taken. Also, depending on the manufacturer's operating policy, this is the point in the operation where machine part identity is established.

The next level of inspection, which is also performed by the contractor, involves bench and roving inspectors where samples are selected from the output of a particular operation. The purpose of this inspection level is three-fold. It serves as a check on the machine operator; it gives the contractor added assurance that his product will meet government standards; and it provides quantitative data which is used to monitor his process, plot control charts, etc. This level of inspection uses for the most part hand gages but in some instances semi-automatic gages are employed. Here again, frequency of inspection is based upon factors previously mentioned.

At the next level of inspection, the contractor performs final acceptance inspection for the government in accordance with the product technical data package. For the most part, this level of inspection uses hand gages, but in some instances semi-automatic gaging may be used. The acceptance limits used at this inspection level are the final dimensional drawing requirements and the frequency of inspection is defined statistically by the quality levels specified in the technical data package.

The final level of inspection involves a verification by the government that the contractor has performed his inspection properly. This inspection uses the same gages as the previous level usually at a much lower frequency.

In regard to the requirements of current acceptance procedures, the contractor is required to provide a quality control plan, since the product specification lists the minimum inspection necessary for acceptance. The intent of the quality control plan is to assure the government that the contractor will provide adequate process control such that final acceptance requirements will be met.

In terms of final acceptance, two basic standards are used: MTD-STD-105D and MIL-STD-1235A. MIL-STD-105D is designed for a batch-type operation. In this case, product is processed in batches or groups and a random sample is selected from each batch for inspection. This type of operation requires storage areas, batch identification and a screening capability in the event that the specified number of allowable defectives is exceeded as determined by the sample selected.

The other standard used for acceptance, MIL-STD-1235A, provides for continuous sampling and is more appropriate for a high volume mass production system. This plan requires an initial 100% inspection of product until a specified quantity of continuous product is accepted. Once this point is reached, inspection can be reduced to sampling and under certain levels, the sampling can be reduced even further as the quality level increases based on inspection history. Once a defective part is discovered during sampling, however, 100% inspection must be reinstated and the contractor must requalify for sampling. A key point to remember is that MIL-STD-1235A stipulates a limit as to how much 100% inspection can be performed. Once this limit is reached without qualifying for sampling, the line must be shut down and corrective action taken.

Once a baseline for current inspection procedures was established, it was decided to survey industry to determine the level of advancement they have made in the field of automated inspection technology. Over 22 companies were contacted during this survey including developers of inspection equipment and manufacturers using this equipment.

The most dramatic difference between inspection systems used in artillery manufacture and those used in industry was the degree of automation and sophistication of equipment used commercially. In this area industry has made great strides and major companies, such as those in the automative field, are in the process of implementing 100% automated inspection. Reasons for this direction are economics (labor costs are high) reliability (visual/manual inspection methods are relatively unreliable) and product liability laws where it is essential that product quality is established with the most precise and reliable methods and adequately documented.

The degree of inspection equipment complexity developed for industry was found to vary from simple automation of attribute inspection of parts for one or two dimensional characteristics to complete inspection systems built as an integral part of the manufacturing equipment supported by data processing equipment which analyzes variable data for a number of characteristics, develops trends and provides direct feedback to the manufacturing equipment for automatic tool adjustment. In one particular application, automated inspection was used to measure components; categorize them according to size, and then later culling out certain sizes for selective assembly of a finished item. In this case, the inspection system is used not only for measurement purposes but also for traceability of parts.

C. CRITIQUE

Reviewing current artillery metal parts manufacturing systems, it becomes obvious that the inspection functions rely almost entirely on human/visual methods. Also, it is recognized that current acceptance procedures are geared around this method of inspection, even to the point where acceptance standards are used. In industry, however, just the opposite situation is taking place where automation is the byword and every effort is being made to replace the manual/visual techniques with automation. One of the major reasons for this, of course, is the high cost of labor in comparison to economic studies made by the gage manufacturers who have developed automated inspection systems that are now competitive to the point where equipment investment costs can be written off in a very short time. Also, with product liability being of major concern companies are diverting to more reliable means of assuring product quality.

In terms of reliability, human engineering studies have shown that a reliability of 80% would be expected for the simplest human judgement type of inspection. The unreliability of manual/visual type inspection is recognized in current artillery manufacturing systems where experience has shown that critical characteristics such as metal defects are subjected to 300% (and in some cases 600%) inspection. Even so, there have been some instances where critically defective material has been shipped to load plants.

On the opposite side of the ledger is the relatively high investment costs for automated inspection equipment. In developing an inspection system the costs must certainly be considered and compared with the labor costs of using current test methods. Obviously a favorable savings to investment ratio must result for economic justification of an automated inspection system.

In addition to the reliability and economic aspects, there are other equally important factors which must be considered before the modernized inspection system can be properly defined. Some of these factors are listed below:

1. Compatibility of the inspection system with a modernized process.
2. A totally integrated inspection system.
3. Traceability of defective parts to the machine producing them.
4. Removal of defective parts before they enter the main flow.
5. Minimize production downtime and scrap.

Analyzing the current inspection system, two factors become immediately apparent; first, the current system because of its manual/visual nature is quite flexible in that inspection needs can be simply compensated for by adding, transferring or reducing the number of inspectors; secondly, a manual/visual system as we now know it is not compatible with a modernized system where automated machinery and handling systems are used. The superpositioning of a manual inspection system on an automated manufacturing line is considered to be impractical, particularly when one realizes the vast number of inspectors and inspection space used in the current systems. Also, with the intended use of automated metal-working equipment with automatic load and unload features the machine level inspection previously described cannot be readily accommodated.

Another factor which must be addressed is the availability or "state-of-the-art" inspection techniques for those requirements which are peculiar to ammunition components and which have not been sufficiently developed to date. These areas are generally associated with visual inspections where discrimination has been left up to the inspector.

These various aspects and factors are just some of the issues which must be resolved before a meaningful definition of the modernized inspection system can be developed. In fact, the selection of the eventual inspection system must of necessity not limit consideration to techniques and test methods but also must place equal importance on the way ammunition will be accepted in the future. In other words, in addition to modernizing the way parts will be inspected, one must also modernize the way ammunition is accepted and therefore major revamping of technical data packages is inevitable.

D. STUDIES

Based on information gathered and a preliminary analysis of current systems vs. modernization requirements several study efforts are currently being conducted. These studies can be categorized into two types. One type addresses inspection procedures and the methods to be used to determine acceptability of product manufactured using the modernized system. The other type of study addresses inspection equipment technology and the development of automated inspection techniques.

In considering the first study category, three major areas are addressed. These areas include:

1. A system definition study to define the basic modernized inspection system to be used.

2. A study evaluating the integration of process control and final acceptance inspection.

3. A complete evaluation of product technical data packages to assure compatibility with the modernized production program.

The inspection equipment type studies address those current inspection needs which require further development of reliable automated techniques to replace current manual/visual methods which are not compatible with modernized manufacture of artillery metal parts. These studies include:

1. Automated non-destructive inspection for critical metal defects.
2. Automated inspection of internal cavity surfaces.
3. Automated thread gaging.
4. Automated raw material inspection.
5. Automated gaging of hot forgings.

In regard to those inspection areas which are presently being performed manually but have not been identified for study, our investigations have shown that these requirements can be met by the gaging industry and therefore do not warrant a special effort.

The system definition study is considered to be critical to the entire program and certainly will have a significant impact on all other activities. The results of this study will essentially provide the foundation for the modernized inspection system. It addresses such factors as economics (investment costs vs. labor costs) the effect of inspection on other systems such as manufacture and material handling, the effect of inspection on productivity and most of all the definition of an inspection system which will be compatible with modernized manufacture while at the same time provide the same degree of product quality assurance.

As a part of MM&TE Project 6520, a complete review and definition of current artillery manufacturing inspection systems was accomplished. This review provided the information previously mentioned in which all aspects of inspection (from incoming raw material to out-going packaged product) were considered.

Under general support to project 5762532, considerable effort was made toward establishing the basic inspection procedure to be used in the modernized systems.

This effort, which included the formation of a dedicated team sponsored by the Project Manager for Munition Production Base Modernization, concentrated on the evaluation of several inspection approaches ranging from 100% automated inspection to manual inspection similar to current procedures. A number of factors or objectives were considered in this evaluation including costs (investment vs. operating), material handling, part identification and traceability, product quality assurance, productivity (downtime and scrap) and facility requirements.

Based on this evaluation, it was established that in general, 100% automated inspection at each machine is the most effective and economical method of inspection.

To illustrate in terms of economics, an analysis was performed comparing current manual inspection systems with one which would be totally automated and integrated with the production line. The analysis delved into specific manufacturing operations as well as the complete line; comparing equipment investment cost with various combinations of manual inspection support costs. To illustrate the economic effect of inspection a typical machining operation was selected where 44 machines are performing the same operation. Under the manual system, each machine would employ an operator who would perform certain inspection functions. In new modernized production plants, this operator is no longer needed and his inspection function is replaced with automatic inspection equipment. Using the Army's ten year discounted economic analysis procedure, the following cost data was generated:

Basis of Estimate:

Production Rate: 1$\overline{M}$ Parts/Month
3-8-5 Shift

Labor Cost: $5/Hr

Estimated Unit Equipment Cost: $40,000

Yr.	Present Labor Cost	New Labor Cost	Difference	Discount Factor	Discounted Differential Cost
1	1,372,800	0	1,372,800	.954	1,309,651
2	1,372,800	0	1,372,800	.864	1,186,099
3	1,372,800	0	1,372,800	.788	1,081,766
4	1,372,800	0	1,372,800	.717	984,298
5	1,372,800	0	1,372,800	.652	895,066
6	1,372,800	0	1,372,800	.591	811,325
7	1,372,800	0	1,372,800	.538	738,566
8	1,372,800	0	1,372,800	.489	671,299

Yr.	Present Labor Cost	New Labor Cost	Difference	Discount Factor	Discounted Differential Cost
9	1,372,800	0	1,372,800	.455	610,896
10	1,372,800	0	1,372,800	.405	555,984
TOTAL					$8,844,950

Cost of 11 Inspection Units 44 X 40,000 = 1,760,000

Savings/Investment Ratio 8,844,950/1,760,000 = 5.03

This example illustrates the potential savings in labor costs when using automated gaging. Over a ten year period, for just one operation a potential savings of almost $9 million exists. The savings to investment ratio of 5 to 1 is also considered to be most encouraging.

It is recognized that costs used in these analysis are only estimated and the actual equipment costs could deviate somewhat from the figures used. The labor costs, however, are real and if anything, will most likely rise. With the significant amount of potential savings, one can see that even if the estimated investment costs are doubled, a most favorable savings to investment ratio (2.5:1) would still result.

E. CONCLUSIONS:

1. Current inspection methods in artillery metal parts plants rely for the most part on manual and visual methods of inspection. These methods are not compatible with a modernized process where it is anticipated that automation will be employed wherever possible.

2. Industry has made great strides in the automation of inspection and the interfacing of the inspection with automatic metal working and material handling equipment.

3. Current acceptance procedures must be reviewed and most likely revised to assure compatibility with continuous flow, high speed manufacture.

4. In general, 100% automated inspection at the machine offers the most reliable, efficient and cost effective system.

F. RECOMMENDATION:

1. Pursue those types of inspection operations identified as MM&T efforts and funded under P-16 projects.

2. Revise current acceptance procedures to assure compatibility with modernized methods of manufacture while at the same time maintaining equal or better product assurance.

SECTION SEVEN

EQUIPMENT

A. INTRODUCTION

Although equipment has been discussed to some extent in the previous sections of this report, particularly billet separation, forming, and machining, it is believed necessary to emphasize equipment as a separate entity in this report.

B. PROJECTILE MANUFACTURING PLANT PRACTICE

The plant surveys revealed that equipment in the plants seemed to vary in two basic areas; one is condition and the other is age.

With regard to condition, it was observed that some plants appeared to keep their production equipment in very good to excellent condition whereas other plants did not appear to maintain their equipment at the same quality level. One plant was observed during the period of this study, putting its equipment into layaway and then in a relatively short time, bringing the equipment out of layaway and back into production. Since this plant maintained its equipment in good condition while operating, and since it went to great care in preparing the equipment for layaway, its experience in bringing the equipment out of layaway and back into production was very good. It is recognized that the equipment had been in layaway for only a short period of time but previously, when the equipment was brought out of layaway, very little difficulty was experienced.

C. CRITIQUE

It appears that improved maintenance and layaway procedures should be established to standardize procedures from one contractor to the next in order to gain maximum operating life and efficiency from the Government-Owned production equipment. Past experience, in general regarding bringing plants out of layaway and up to production rates, has not been particularly good on the most part. Certain items are found to have a fixed shelf life and after that should be replaced. These items, such as seals on hydraulic units, insulation and wiring, electrical components, etc., should be replaced on a periodic basis after a proper shelf life has been established. It is believed, based on discussion with operating contractors, that certain components when brought out of layaway, go thru a short term mortality rate similar in nature to the infant mortality rate of a new component. For example, a relay panel brought out of layaway when tested may indicate several relays are bad and these will be replaced. However, once the equipment is put into operation the relays that tested satisfactorily initially

begin to fail after a very short time in operation. It appears, based on some discussion with certain equipment manufacturers, that much of this mortality could be predicted based on specific tests to be developed or data already collected. It might be, for instance, that all the relays should be replaced rather than experience continuous failures while trying to meet production. Since mortality is a function of time in layaway, such decisions would be based on these factors and economics.

Certainly, equipment reliability and performance can be improved by improved layaway procedures. For example: machine tools may have to be disassembled to prevent bearing creep and shafts and bearings may have to be covered with preservatives and placed on the floor where they can be periodically inspected. These procedures should help to extend layaway time and reduce start-up mortality rates. The main benefit to be gained here, of course, is reduced lead time to bring a line up to production with improved reliability.

During the survey it was found that no one has any in-house capability to predict expected performance of equipment being brought out of layaway. Yet discussion with industrial concerns indicate that technology exists today to develop predictive programs and periodic tests so that an assessment of the present condition of equipment can be made and the future performance predicted. Furthermore, the reliability of the assessment itself can be determined. This would require an analysis of equipment and a determination of the condition of that equipment at the present time and a reliable layaway program. In the case of new equipment, however, much of this information exists and a predictive program could more easily be developed.

With regard to age of equipment, it was found to vary considerably. Some equipment was purchased before 1950 and, of course, new equipment is being purchased today. The older equipment is generally less productive, requires more manpower per unit produced, has low reliability and is usually underpowered and manually operated. The new equipment is usually automatic and should have ample power to produce efficiently through the 1980's. A problem can occur when the old equipment is mixed with the new. It appears that the placement of older lathes doing essentially the same work will result in an inefficient operation of the new equipment and possibly cause trouble with operation of the old equipment. Normally this is not a problem under the modernization program for the GOCO plants since all of the equipment is scheduled for replacement where required. However, in those plants where voids in the line are to be filled with modern equipment, care must be taken to purchase equipment similar in performance to the rest of the equipment in the line even if this means the purchase of a piece of equipment that does not take advantage of all the cost saving features available today.

The plant survey also revealed that on-line maintenance programs vary considerably from one plant to another. As might be expected, this results in the equipment experiencing varying degrees of failure. Since it is apparent that some maintenance procedures are better than others it might be well to investigate in detail the existing

maintenance procedures used in GOCO plants and related industries in an attempt to improve procedures and standardize, where necessary.

In the procurement of equipment the first action to be taken should be a definition of the function the equipment is expected to perform. In the modernization of the GOCO plants it can be seen this might be a simpler task than for the non-GOCO plants. The reason for this is that the item the GOCO plant is expected to produce in an emergency is relatively well defined. In the case of the non-GOCO plants changes to production requirements can be expected from time to time. Because of the projected or expected change in requirements the equipment to be purchased for or by the non-GOCO should be more flexible in capability even if this flexibility results in some loss of production efficiency. An example would be where a firm requirement exists to produce 105MM M1 type projectiles at the production rate of one million per month with only the possibility of the length of projectile changing. In this case, a special machine tool might be purchased. On the other hand, where a requirement exists to produce thirty thousand units per month of a particular tank round, where the design might change significantly or be replaced by a different design, then a machine tool capable of accommodating this change, possibly a Numerical Control (NC) machine, might be the type of equipment to purchase. The procurement of flexible equipment offers the most opportunities to accommodate product changes. The selection of flexible equipment such as NC equipment would also permit the use of pre-programmed tapes which should reduce lead time. These tapes can be kept in storage and altered or new ones prepared as the product design is altered or replaced. The use of flexible equipment also permits the use of this equipment elsewhere to accommodate production requirements as they vary for different items from time to time.

It appears therefore that each plant and each requirement in that plant, whether it is a GOCO or non-GOCO plant, should be defined and a determination made as to the basic type of equipment that should be purchased prior to writing specifications for that equipment.

D. CONCLUSIONS

The information obtained from the ammunition plant surveys conducted under this project and conversations with equipment manufacturers indicate that several improvements to the current methods of plant layaway can be made through the implementation of the following procedures:

(1) Periodic replacement of all stored parts and materials whose shelf lives will not survive layaway.

(2) Replacement, prior to production, of those items whose reactivation mortalities rates would adversely affect production startup.

(3) Periodic testing of manufacturing equipment in layaway to assess equipment condition and probability of successful future operation.

(4) Standardization of layaway procedures for all GOCO plants.

(5) Determination and implementation of optimum method of equipment preservation and storage.

Plant maintenance programs vary considerably among the munitions plants visited. This has resulted in varying degrees of equipment failure. Improved and standardized maintenance of production equipment will increase both equipment life and reliability.

The functional requirements of manufacturing equipment should be defined prior to purchase. When the item to be produced is well defined, as in the case of GOCO plants, equipment should be purchased to that particular item. In those plants where the item requirements may change, flexible equipment such as numerical controlled lathes should be considered.

F. RECOMMENDATIONS

A study to determine the optimum methods of plant layaway is required. This study would provide the information necessary to reduce lead time to mobilization through analysis and determination of:

(1) Shelf lives of all stored items.

(2) Projected reactivation mortalities of manufacturing equipment in layaway.

(3) Methods of testing equipment condition while in layaway.

(4) Optimization of equipment preservation.

Problems and delays encountered during start up of production equipment at the onset of the Korean and SEA conflicts would be identified and means of correction developed.

Based on the information gained, specific guidelines, procedures, specifications, etc. would be prepared and validated for application to present and future layaway of equipment and facilities.

SECTION EIGHT

ENERGY

A. INTRODUCTION

Energy is a recent problem in metal parts production plants. This section will discuss the problems being encountered and indicate what steps can be taken to control and reduce energy consumption.

B. PROJECTILE MANUFACTURING PRACTICE

During the plant surveys, it was found that although most of the plants had a reasonable knowledge of their total energy usage, a definitive knowledge of how and where the energy was being consumed was not known. Certain major areas such as gas and oil consumption for furnaces could be identified, but such requirements as electrical consumption for equipment, causes of peak loads, space heating demands, energy for boilers, etc., were not known or defined.

The major concern of the plants was not where the energy was being used, but rather the availability of energy sources such as oil, gas and electricity. Several plants have received notices that they can be expected to have their natural gas requirements shut-off during certain winter months when peak demands occur. A few plants have been advised that natural gas will not be available at all within a few years. This type notice has prompted many plants to consider the use of alternate energy sources, usually oil. A few plants were possible have established the capability of operating furnaces on gas and switching to oil when gas it not available. Other plants are considering switching entirely to oil since there will not be gas available. Still other plants are looking to electricity as their sole energy supply. This would mean the installation of electric billet or mult heaters and electric heat treating equipment and electric stress relieve furnaces. The making of steam in boilers has not yet beer fully addressed.

C. CRITIQUE

Based on the findings of the survey it is obvious that the major concern at this time is finding a reliable energy source and then reducing energy costs.

One way of reducing electric energy costs has been proposed thru the monitoring of peak load demand. Most industrial plants are billed based on their peak load demand. If this peak load demand is reduced then their billing is likewise reduced. Several companies sell equipment that constantly monitors the on-line demand load.

When the load begins to exceed pre-determined limits, based on empirical data previously established thru testing, the equipment begins to shut down unnecessary equipment for a short period of time. An example might be that if a peak load is observed to approach an unacceptable limit then air conditioners; ventilating fans, pumps in non-critical areas might be shut off for a short period of time. Once the demand drops, this equipment is turned back on or this equipment is turned on and other equipment is turned off.

While this procedure results in reducing peak load and obviously has benefit in reducing operating cost the actual energy reduction would not be very great.

Certainly more positive approaches could be taken toward reducing energy consumption. As discussed in the section on heating and heat treatment, considerable quantities of energy are being used unnecessarily and certainly energy conservation steps could be taken that would have tremendous impact on energy reduction and cost savings.

For example, present oil furnaces are operating in the range of 15% to 30% thermal efficiency where an area of 70% thermal efficiency should be considered.

In the area of forming the use of mechanical presses in lieu of hydraulic can result in significant savings. In one particular plant mentioned previously a planned system of 5 mechanical forge presses and 10 hydraulic draw presses was replaced with 5 larger mechanical presses capable of performing the draw as a part of the forging operation. The connected horsepower for the 5 mechanical forge presses and 10 hydraulic draw presses totaled 10,000 H.P. Whereas the five mechanical presses capable of also doing the draw have a total connected horsepower of 2,750.

In the machining lines larger horsepower lathes have been required for modernization. These lathes have increased productivity and therefore require no additional energy per projectile produced. However, it has been found that hydraulic systems used for transferring parts thru a lathe are very inefficient. In the case of procuring rough turn lathes at a 105MM M1 plant, hydraulic transfer systems were used. This particular hydraulic system required a 40 HP motor, plus cooler to cool the oil heated up in the hydraulic system. The motor pumps against a dead head whether transfer is being made or not. Thus the 40 HP current requirement is always on-line. In addition a heat exchanger pump and cooling tower are required to disipate this heat. When one considers 42 lathes were purchased we have:

42 lathes X 40 HP/lathe 1680 HP

being used. In a more recent procurement transfer units that did not use hydraulic systems were purchased for similar lathes. Here 7 1/2 HP motors were required. The motors are in use only while transfer is being accomplished which is estimated at 10% of the cycle time. The total transfer power requirement in this system is:

7.5 HP/lathe X 42 lathes X 10% usage = 31.5 HP

Thus it can be seen that for just a Rough Turn operation, energy in transfer could be reduced from 1680 HP to 31.5 HP.

Clearly it can be seen that a study is required of almost every operation in each plant to not only catalogue and measure the energy consumption but to select alternatives to reduce energy consumption.

One private concern has advised us that they have started such a procedure in one of their industrial plants. They identified every energy requirement, determined its need and possible alternatives. So far they have reduced energy consumption by twenty-five percent (25%) and expect to do more. This, by the way, was done in a relatively modern plant. It is believed that energy savings approaching fifty percent (50%) in some of our older plants is not unrealistic and twenty-five percent (25%) should be obtainable in most plants in operation. Of course studies would be required to consider the cost of achieving a lower energy consumption and the payback ratio must be determined. On the other hand, as the above mentioned contractor explained that by cutting back their energy requirements they were able to maintain their operation without interruption during energy cutbacks by the utility companies that service them. They considered this fact almost invaluable.

D. STUDIES

A program to identify needed energy conservation measures and to determine methods for efficient energy utilization at Army Ammunition Plants has recently been undertaken under MM&TE Project #5764281 titled, "Methods for Conservation of Energy at Army Ammunition Plants."

The program is divided into two subprojects which are being conducted by Picatinny and Frankford Arsenals. The Picatinny subproject focuses on energy studies at munitions load and pack plants while the Frankford subproject examines energy at munitions metal parts plants. Two specific areas of investigation are currently being initiated by Frankford Arsenal.

1. "Process Energy Inventory for Metal Parts" - This task will determine from plant surveys: a. What energy is being used; b. Where the energy is being used; c. When the energy is being used; d. Why the energy is being used. The information will be utilized to develop a computer energy model such that actual energy consumption and efficiency of use can be determined for each manufacturing step. The model will pinpoint areas wherein energy can be saved without the cost of a major program and identify those areas where efficiency can be improved with engineering studies.

2. "Investigation of Reduced Forging Temperatures" – This task will be conducted in two phases. The first phase will determine the effect of lower forging temperature on forging tonnage requirements. Resultant metallurgical properties and the dimensional characteristics of the forged product will be examined. This phase will provide the necessary data to conduct an engineering trade-off study to determine an optimum forging temperature. The second phase will involve the production of 10,000 projectiles at the optimum forming temperatures to prove out the data obtained in the first phase. If successful, this task will provide the data necessary to reduce the energy required for forging artillery metal parts.

Contingent upon funding, several additional areas of energy conservation for metal parts manufacture are planned for investigation under this project:

1. Reduced heat for phosphating and cleaning.
2. Improved furnace efficiency by utilization of waste heat.
3. Reduced heat for forging through lower weight mults.

E. CONCLUSIONS

Energy consumption can be reduced in almost every operation found in metal parts plants. Increased thermal efficiencies of furnaces, use of mechanical in lieu of hydraulic presses, lower forging temperature and lower billet weight are some of the areas which can significantly contribute to energy savings in the artillery MPTS facilities.

F. RECOMMENDATIONS

Due to the present and future expectations of the availability of energy sources, it is imperative that the energy requirements in our MPTS facilities be better defined and alternate energy sources be utilized for existing process operations.

Energy savings is a very cost effective method in reducing the overall manufacturing cost of an item and should be thoroughly investigated for all avenues of possible savings.

It is recommended that MM&TE Project #5764281 titled, "Methods for Conservation of Energy at Army Ammunition Plants" be continued and future funding be made available if needed to implement other areas of energy conservation as outlined under the study portion of this section.

SECTION NINE

SUMMARY OF CONCLUSIONS

As a result of the surveys conducted of private industry and projectile metal parts plants, literature searches, engineering evaluations and specific studies conducted, it is concluded that modern equipment and more efficient manufacturing techniques can be applied to artillery metal parts plants with the expectation of beneficial results, especially in the form of reduction in direct labor.

With the increased productivity and the automatic load and unload features of recent equipment designs, the manpower costs required to produce a given unit under production conditions could be significantly reduced over present practice. With the incorporation of modern machine tools coupled with an integrated automatic material handling and inspection system, direct labor in the form of manhours could be reduced at least fifty percent (50%) in most cases. Similar type direct labor reduction can also be expected in other areas such as forging, heat treating, painting, etc.

Through the use of a system approach to manufacturing operations such as hot shearing and preheat, lube, induction heat prior to nose, additional savings in manpower costs should be realized.

A second major area for cost savings is the reduction of starting material cost through use of smaller mults. The new presses purchased under plant modernization programs should be capable of utilizing contour tooling and tightened draw rings which should significantly reduce the cost of the starting material.

In the area of metal removal, cost savings can be realized through the use of new cutting tools, improved cutting fluids and alternate methods of metal removal.

Improved thermal efficiency of furnaces should lead to reduced fuel consumption which would both increase the probability of plant operation during periods of fuel cut backs by the utility companies and reduce the manufacturing costs of projectile metal parts.

By defining manufacturing parameters and through the use of math modeling, lead time to production can be decreased and the optimum equipment/process can be utilized for artillery MPTS manufacture.

Layaway procedures are important tools in the government's overall plan for M day requirements. By optimizing the procedures in order to further facilitate equipment readiness, improved reliability in manufacturing lines may be realized.

In conclusion, this project has been of great assistance in pointing out risk factors and provides the basis for the future MM&T work to be performed.

SECTION TEN

SUMMARY OF RECOMMENDATIONS

Many benefits are to be accrued if the recommendations of this study are implemented in the form of future engineering studies. In addition to the cost savings to be realized from these studies, future projectile designs and their compatibility to known manufacturing techniques will be ascertained and the optimum production/process realized through mathematical modeling, thus reducing the leadtime from projectile concept of production.

The intent of this report is to recommend what future MM&T Engineering Studies are needed to investigate in detail the latest state-of-the-art production techniques and their applicability to artillery.

The following proposed MM&T projects have been developed from the findings of this project:

(1) Project No. 5776730 – Squeeze Casting of Munitions Hardware.

(2) Project No. 5776719 – Investigation of Warm Forming as an Alternate Method of Manufacture for Artillery/Mortar Metal Parts.

(3) Project No. 5776716 – Development of Mathematical Modeling of Forming Operations for Current and Future Artillery Metal Parts Design.

(4) Project No. 5776714 – Feasibility and Manufacturing Study of Reduced Steel Requirements for Artillery Metal Parts Fabrication.

(5) Project No. 5776713 – Investigation of State-of-the-Art of Computer Hardware for Automatic Control of Artillery Metal Parts Manufacture.

(6) Project No. 5776712 – Engineering Studies on the Feasibility of Utilizing Multiple Linkage Mechanical Presses for Long Stroke Applications.

(7) Project No. 5776711 – Investigation of Optimum Methods of Layaway of Artillery Metal Parts Plants.

(8) Project No. 5776682 – Simulation of Ammunition Product Lines.

(9) Project No. 5776632 – Automated Inspection Devices for Artillery Projectiles in Modernized Plants.

(10) Project No. 5776706 – Metal Removal for Artillery Metal Parts.

(11) Project No. 5776708 – Development of Chip Handling Systems by Determination and Interface of an Integrated System for Artillery Metal Parts Manufacturing Plants.

The time and cost requirements for the proposed projects are shown on the following chart. All costs are in FY77 Dollars.

Project No.	FY77$	FY78$	FY79$	FY80$	TOTAL$
5776730	71K	0	320K	490K	881K
5776719	402K	53K	0	0	455K
5776716	295K	310K	320K	340K	1265K
5776714	259K	412K	1076K	0	1747K
5776713	171K	53K	0	0	224K
5776712	54K	54K	0	0	108K
5776711	177K	118K	59K	0	354K
5776682	295K	141K	0	0	436K
5776632	589K	236K	0	0	825K
5776706	479K	795K	290K	195K	1759K
5776708	53K	29K	0	0	82K
TOTAL	2845K	2201K	2065K	1025K	8136K

It is recommended that the above proposed studies by implemented so as to enhance the overall modernization programs in the MPTS producing facilities. Furthermore, it is recommended that the on-going studies on hot shearing, induction heat treating, automatic inspection techniques and energy be continued.

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